University Relations Program

ANNUAL REPORT

FY1998 & 1999

Lawrence Livermore National Laboratory
Managed by the University of California for the Department of Energy
UCRL-LR-140316

DISCLAIMER

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University Relations Overview

The mission of the University Relations Program is to contribute to the intellectual vitality of the University, Laboratory, and industrial communities by fostering research collaborations in basic and applied science.

Collaborations between DOE national laboratory researchers and educational institutions serve several important purposes:

- They enhance the training of young people in science and technology fields important to DOE;
- They establish fruitful contacts for recruiting future laboratory staff members;
- They directly benefit DOE research programs, adding expertise and new perspectives;
- They provide a path by which unique DOE facilities and expertise can benefit the general U.S. research community.

In recognition of the importance of these roles, the Lawrence Livermore National Laboratory (LLNL) has established its University Relations Program (URP) to provide coordination among education-related programs at LLNL and to develop new initiatives to attain DOE goals.

The figure below illustrates the chain of education and collaborative research activities. LLNL's programs span this educational chain in a balanced fashion.

Five University-Laboratory Institutes form a centerpiece of LLNL's research collaborations with universities: the Center for Accelerator Mass Spectrometry (CAMS), the Institute of Geophysics and Planetary Physics (IGPP), the Institute for Laser Science and Applications (ILSA), the Institute for Scientific Computing Research (ISCR), and the Materials Research Institute (MRI).

Each Institute has its own suite of offices (some have labs as well), with meeting rooms and open areas to encourage intellectual interactions between LLNL staff, students, faculty and visitors. These offices are all located outside the classified areas

K - 12 Science and Technology Education

Student Outreach:

- Fun with Science
- Science on Saturday
- Expanding Your Horizons
- Math-Challenge
- Tri-Valley Science and Engineering Fair
- Explorer Post
- Classroom Speakers Bureau
- Critical Issues Forum

Teacher Training:

- Workshops
- Future Scientists and Engineers of America
- Technology Resource Center (TRC)

College Programs

- Student Internships at LLNL
- Research Collaborations Program for HBCUs and MIs
- ASCI Capstone / Pipeline Program
- Actinide Sciences Summer School Program (ASSSP)
- Military Academy Research Associates (MARA)
- National Security Cooperative Program (NSC)
- Undergraduate Research Seminars (URS)
- Partnership for Environmental Technology Education (PETE)
- Laser Electro-Optics Technician Program, Los Positas College

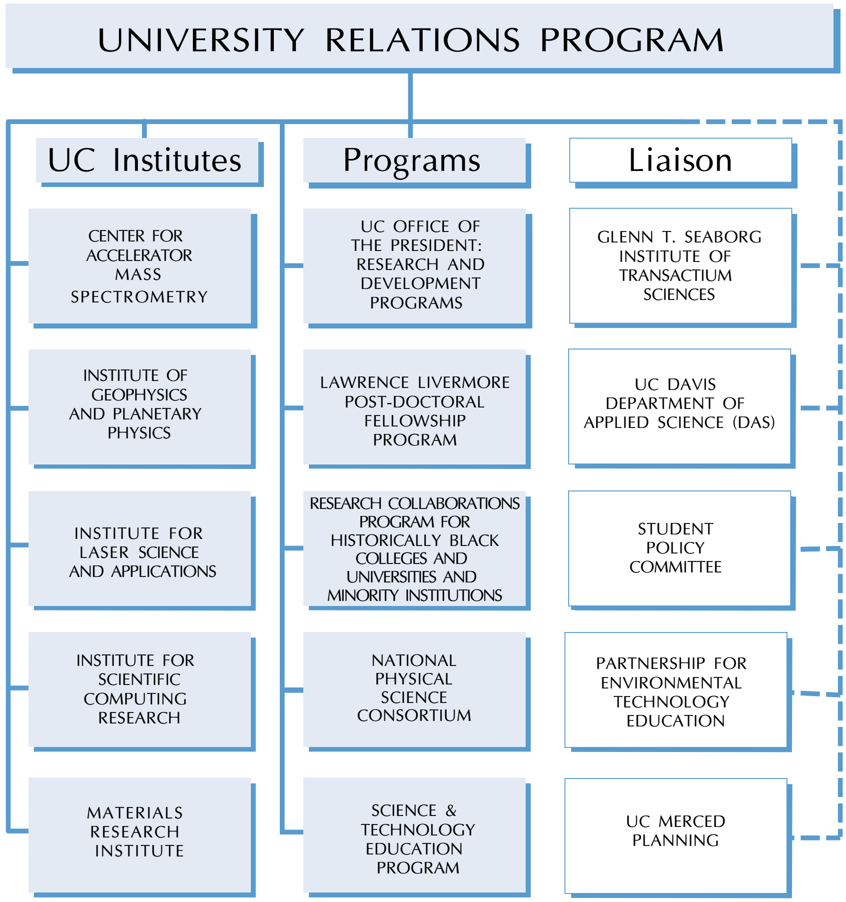
Graduate Level Programs

- UC Davis Department of Applied Sciences (DAS)
- Student Employee Graduate Research Fellowships
- National Physical Science Consortium
- URP Institutes
- Graduate student research sponsored by LLNL Institutes

LLNL Employees (Post-doc Career)

- Lawrence Livermore Post Doctoral Fellowship Program
- URP Institutes

DOE NEEDS



URP organization FY 1998 — 1999.

of the Laboratory site. Each Institute hosts an active seminar series and visitor program and provides a focus for communication between LLNL researchers and the broad academic community.

The full-time LLNL staff at each Institute is deliberately kept lean, and usually consists of only a few LLNL career employees whose function is to "anchor" a much larger group of students and visiting faculty, and facilitate their interactions with LLNL programs.

The University Relations Program is also responsible for other research collaboration programs with the university community. These include the UC Directed Research and Development Program (UCDRD), and the Research Collaborations Program for Historically Black Colleges and Universities and Minority Institutions.

As part of the UCDRD funding from the UC Office of the President, each Institute runs a University Collaborative Research Program. This Program consists of small awards to encourage collaborations between the UC faculty and Lab researchers. These awards, which primarily fund graduate students, are listed in the back of each Institute's section.

Support (both financial and managerial) for top-notch postdoctoral researchers and pre-doctoral fellows is a crucial link in the chain leading from education to research experience to a scientific career. The University Relations Program runs the Lawrence Livermore Postdoctoral Fellowship Program on behalf of the LLNL

"LLNL's University Relations Program serves a vital role in the professional development of numerous faculty and students at the University of California. Through the creation of programs and opportunities, the URP expands the research and education experience of hundreds of members of the UC community. Perhaps most important are the opportunities for UC students to experience a research environment at LLNL that stresses cross-disciplinary cooperation and has contact with private sector research agendas . . . The URP makes a unique and valuable contribution to the research and teaching missions of the University of California."

Robert Shelton, Vice Provost for Research, University of California

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Paul R. Dickinson (2000)

Personnel Manager

Clea Marples

Director and coordinates LLNL participation in the National Physical Science Consortium, a program of pre-doctoral fellowships aimed primarily, but not exclusively, at increasing the representation of women and minorities in the physical sciences.

LLNL's Science and Technology Education Program (STEP) supports a variety of internships at LLNL for college students. This type of positive experience in the "real world of research" is often a crucial component of a college student's decision to continue his or her science education and to go on to graduate school.

Also at the college level, the Research Collaborations Program for Historically Black Colleges and Universities and Minority Institutions brings minority college students to LLNL as summer interns, along with their faculty mentors, to participate in research projects side by side with LLNL scientists and engineers.

At the community college level, LLNL co-sponsors an optical technology curriculum at the nearby Las Positas College, and co-founded the community college-focused Partnership for Environmental Technology Education (PETE).

LLNL's Science and Technology Education Program (STEP) also oversees programs for kindergarten through twelfth grade students and teachers. In the area of teacher training, STEP ran teacher workshops on Laser Science and Optics and growing crystals in 1998 – 1999. In the area of student programs, STEP ran the Fun with Science program, a van with science activities that travels to regional schools, and the Science on Saturdays program, a series of lecture-demonstrations aimed at students, teachers and parents from the local community.

The U.S. at present scores very poorly in the quality of its science education when compared with other countries throughout the world. In many physical science and engineering fields, less than half of all graduate students at U.S. universities are U.S. citizens. Yet high-technology institutions such as U.S. national laboratories will be relying on a continuing stream of highly trained young people for their future workforce.

URP lead an LLNL-wide Education Task Force to categorize and understand the role of all education-related programs at the Laboratory. The results of that work are summarized in the chart on page 7 for all efforts discussed in this report.

We at LLNL have made science education, training and recruitment a focal point of our University Relations Program. We recognize, however, that these steps are only a start. Only through a concerted effort on a national scale, aided by high-technology institutions all across the country, will the nation be able to reverse the current downward trends in the U.S. science and engineering workforce.

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Catagorizing and Prioritizing LLNL Education Programs

◯ = Primary Goal

		Assist LLNL to accomplish its mission, do its research	Establish long-term research collaborations on a national scale	Recruiting	Increase representation of women and minorities	Pipeline	Strengthen science education	External relations	Investment in future national decision makers	Strengthen minority institutions
	University/Laboratory Institutes (CAMS, IGPP, ILSA, ISCR, MRI)	●	◯	●					●	
	Lawrence Livermore National Laboratory Fellowship Program	●		◯				●	●	
	National Physical Science Consortium (NPSC)		●	◯	●	●				
	UC Davis Department of Applied Science (DAS)	●		◯		●		●		
	Research Collaborations Program for Historically Black Colleges and Universities and Minority Institutions	●	●		◯					●
	The Glenn T. Seaborg Institute of Transactinium Sciences	●	●	●		◯				
	Partnership for Environmental Technology Education (PETE)					◯	●	●		
Science Technology Education Program	Expanding Your Horizons (EYH)				◯	●		●		
Science Technology Education Program	Graduate Internships	●			●	◯		●		
Science Technology Education Program	Critical Issues Forum					●	◯	●		
Science Technology Education Program	Centers for Excellence in Student Research (CESRs)					●	◯	●		
Science Technology Education Program	Actinide Science Summer School Program (ASSSP)					●	◯	●		
Science Technology Education Program	National Education Super Computer Program (NESP/Science Visualization)					●	◯	●		
Science Technology Education Program	The Technology Resource Center (TOWER)					●	◯	●		
Science Technology Education Program	Fun with Science (FWS)					●	●	◯		
Science Technology Education Program	Speakers Bureau (LLNL employees who speak at schools)					●	●	◯		
Science Technology Education Program	Science on Saturdays (SOS)					●	●	◯		
Science Technology Education Program	Explorer Post					●	●	◯		
Science Technology Education Program	Future Scientists and Engineers of America (FSEA)					●	●	◯		
Science Technology Education Program	Military Academic Research Associates (MARA)	●				●	●	●	◯	

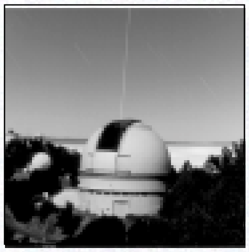
The programs listed on this chart represent those discussed in this report.

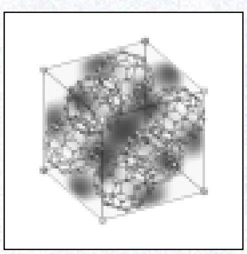
Catagorizing and Prioritizing LLNL Education Programs

○ = Primary Goal

	Assist LLNL to accomplish its mission, do its research	Establish long-term research collaborations on a national scale	Recruiting	Increase representation of women and minorities	Pipeline	Strengthen science education	External relations	Investment in future national decision makers	Strengthen minority institutions
ASCI Alliances	○	●	●					●	
Post-Docs	○		●		●			●	
Summer Employment Program (SEP)	●		○		●			●	
Biology and Biotechnology Research Program Training	●		○		●				
National Consortium for Graduate Degrees for Minorities in Engineering and Science, Inc. (GEM)			●	○	●				
Technician Internships for Native Hawaiians (ALU-LIKE)				○	●	●	●		
Life Gets Better (Florida A&M Univ.)			●	○					
Summer Institute			●	●	○			●	
MOA's with Community College Districts for Vocational Training (MOA)	●				○	●	●		
Engineering Adm. Outreach			●		○		●		
Science Bowls				●	●	○	●		
Science Museum Outreach					●	●	○		
Tri-Valley Science and Engineering Fair (TVSEF)				●	●	●	○		
Science and Engineering Alliance (SEA)			●	●	●				○
American Indian Program (AIP)				●			●		○
Navajo CC Scholarship Program				●		●			○

The programs listed here are educational programs at LLNL which are not directly associated with the University Relations Program.

Institutes

The LLNL Institutes' objective is to improve access to DOE's unique facilities, contribute to science education, strengthen existing LLNL programs, develop new initiatives, and provide open-access space to foster interactions with the academic community.

Center for Accelerator Mass Spectrometry

Institute of Geophysics and Planetary Physics

Institute for Laser Science and Applications

Institute for Scientific Computing Research

Materials Research Institute

Center for Accelerator Mass Spectrometry

The mission of CAMS is to continue to lead the development and application of isotopic abundance measurement and ion-beam analytical techniques that support LLNL missions while enhancing and enabling university research.

Accelerator Mass Spectrometry (AMS) is an exceptionally sensitive technique for measuring concentrations of specific isotopes in relatively small samples, e.g., < 1mg. At LLNL, the Center for AMS (CAMS) makes available to the DOE and university community the most versatile and productive AMS facility in the world. CAMS routinely measures low-abundance isotopes (e.g, less than one part in a trillion) that have multidisciplinary applications: detection of nuclear fuel reprocessing; reconstruction of radiation dosimetry at Hiroshima, Nagasaki and Chernobyl; effects of carcinogens and mutagens; atmospheric and ocean chemistry; archaeology; and paleoclimatology. During 1998–99, CAMS scientists performed approximately 40,000 analyses: a feat that is unmatched by any other AMS facility. It is estimated that CAMS annually performs about 25% of all such analyses throughout the world.

The development and dissemination of AMS technology, coupled to the needs of scientific users, is an appropriate mission for LLNL and is of special value to the University of California (UC) and the Department of Energy (DOE). In particular, CAMS scientists are leading UC- initiated Campus-Laboratory Collaborations (CLCs) in which AMS is being used to address unique problems in earth sciences and biomedicine. These programs have engaged faculty and graduate students from every UC campus and have strengthened related programs at LLNL. Approximately 40 graduate students participated in various CAMS projects in 1998–99. The UC Office of the President has encouraged these relationship.

The scientific expertise of the CAMS staff, coupled with the high throughput of the CAMS facility, have resulted in more than 60 collaborative and fee-for-service relationships with domestic and foreign universities, research institutes, and government agencies. These relationships have resulted in a variety of unique applications in earth, environmental, and biological sciences. Research conducted in collaboration with university faculty during 1998-99 is highlighted below.

CAMS Research Highlights

Biomedical Applications of AMS

CAMS is the world leader in the application of AMS to biomedical science. In 1999, CAMS was awarded a $7 million Research Resource grant by the National Institutes of Health (NIH). This grant, which establishes CAMS as a national center for the application of AMS in the biosciences, was made possible due to the demonstrated experience of developing and leading collaborative research with university scientists. Scientific advances, such as those highlighted below, illustrate unique applications of AMS to the fields of toxicology and nutrition.

AMS is an ideal method for tracing the passage of chemicals through humans and animals without disturbing normal metabolic processes. Rare isotopes of elements found in organic materials are ideal as tracers because they can be incorporated into biomolecules without modifying their natural properties. The molecules of the substance being studied are "tagged" with a relatively rare isotope, typically carbon-14. The tagged molecule can then be followed as it undergoes normal metabolic processes.

Precise determination of chemical processes in humans is made possible by the unrivaled sensitivity of AMS. In collaboration with researchers at UC San Francisco and UC Davis, AMS was used to trace the uptake and elimination of a ^{14}C-labeled herbicide (atrazine) in humans. The aims of this study were to define atrazine up-

Graduate student Adam Love is using a new, compact spectrometer to assess the uptake of tritium by trees at the Nevada Test Site.

take and elimination, and to determine the major metabolites in urine. Excretion rates were determined and samples were chromatographically separated to determine metabolite profiles up to several days after exposure. This proved to be an excellent method for determining the biomarkers needed for developing an assay for occupational exposure to this and other hazardous substances. This study could only be conducted because of the sensitivity of AMS.

Recent progress in the application of AMS to the metabolism of nutrients in humans also has been significant. In collaboration with scientists at UC Davis, studies yielded significant insights into the nature of folate and beta-carotene metabolism in humans. As a result of this work, Dr. Andy Clifford (professor of nutrition at UC Davis) has been awarded follow-on grants from NIH to conduct definitive AMS studies of nutrient metabolism in humans. Such advances are made possible by the unique coupling of campus and DOE Laboratory resources.

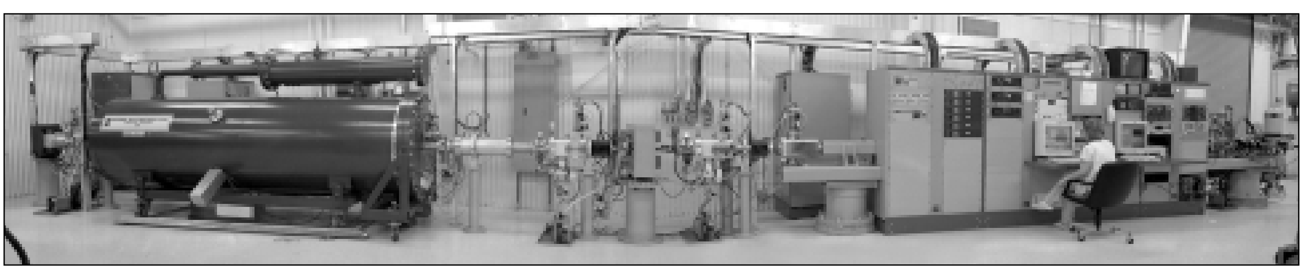
Tritium (^{3}H) is another radioisotope that is extensively used in biological research. Scientists at CAMS have demonstrated that AMS can be used to quantify ^{3}H in milligram-sized biological samples with a 100 to 1000-fold improvement in detection limits when compared to conventional methods. A small AMS machine, devoted exclusively to dedicated ^{3}H spectrometry, has been developed and is undergoing characterization for its application to biomedical and environmental sciences. Researchers from UC San Francisco, UC Berkeley, UC Riverside and the University of Arkansas are collaborating in this effort.

Nuclear Microprobe Investigations of Metal Toxicology

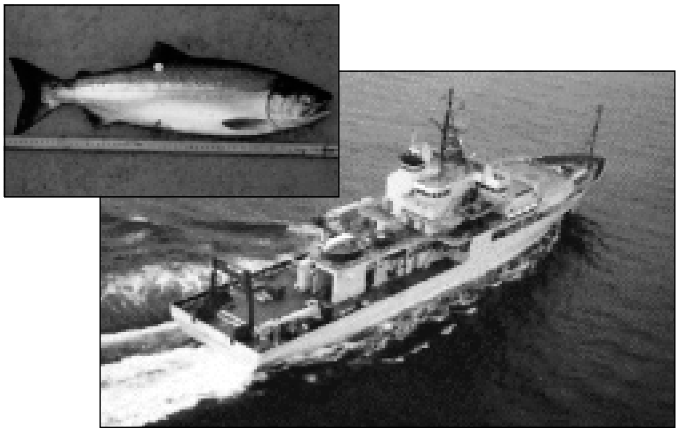
Human exposure risk evaluation is hindered because environmental conditions often deviate from those in laboratory studies. A nuclear microprobe is being used to analyze metals in tissues that are hypothesized to be sites of toxic action. This research is using a combination of laboratory and field studies to evaluate the importance of inhalation as an exposure pathway for metals.

In collaboration with scientists from the University of New Mexico, factors that control the central nervous system (CNS) transport and toxicity of inhaled metals are being defined. The entrance of metals into

"An overwhelming case was made for the need for an AMS resource and a number of outstanding collaborative projects have already been initiated. There was tremendous enthusiasm for the goals of the proposal and for the proposed collaborative research. At the present time, the LLNL resource is clearly the most advanced site in the U.S. to explore the use of AMS in biomedical research." Excerpt from NIH site visit report.



Graduate student Stephanie Jeske operates the CAMS nuclear microprobe that is being used to assess the concentrations and distributions of metals in biological tissues.



Archived salmon scales are being used to obtain a broad range of spatial and temporal information on carbon assimilation in the ocean that is not possible with traditional shipboard techniques.

the CNS via the olfactory pathway is of great interest because chronic exposures are suspected as possible causes in the development of neurodegenerative diseases. This work can be incorporated into risk assessment processes, which will enable risk analysts to more effectively prioritize the risks posed by toxicants present at contaminated sites.

Radiocarbon as an Indicator of Ocean Circulation

The world's oceans play a major role in the sequestration of carbon dioxide from the atmosphere. Understanding the processes through which oceans assimilate and transport carbon dioxide are necessary for, in turn, understanding the global carbon cycle, its relationship to ocean currents, and ultimately, the world's climate.

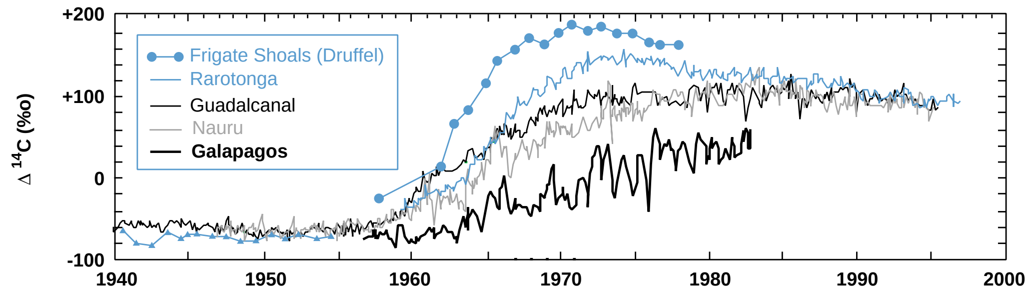
The environmental gradient in ^{14}C that came from atmospheric nuclear testing (so-called "bomb ^{14}C" is being used to track water mass movement in the oceans over the last 100 years. Unlike temperature and salinity, ^{14}C is a conservative tracer in surface waters. The current measurement record, which contains spatial and temporal biases, is incomplete and cannot be used to determine exactly how the circulation of the tropical and sub-polar Pacific varies over seasons to decades. CAMS scientists, in collaboration with researchers from the University of Washington, Harvard University, Columbia University and the Scripps Institute of Oceanography, have developed and applied novel methods for evaluating past ocean circulation patterns and impacts on the global carbon cycle.

Using Salmon Scales to Assess Ocean Circulation in the Sub-polar Pacific

The uptake of CO_2 by the ocean is one of the most important sinks for anthropogenic CO_2 (carbon dioxide resulting from human activities). Ocean General Circulation Models, the nation's best computer models, indicate that oceanic ^{14}C distributions provide major constraints for the model–simulated oceanic circulation fields and CO_2 uptake. In collaboration with faculty at the University of Washington, a new approach for determining the ^{14}C concentrations of the world's oceans, the measurement of the carbon isotope contents of archived salmon scales, is being used to reconstruct the ^{14}C levels of the world's sub-polar ocean surface waters over the last 100 years. This approach takes advantage of the fact that each salmon scale reflects three distinct years of ^{14}C assimilation, and of the fact that different salmon groups swim over (and hence sample) sizeable regions of the world's oceans. In contrast, traditional oceanographic (i.e., shipboard) techniques are limited to measurements of water samples that only reflect the place and time of collection. Results from this study have revealed significant discrepancies between the "real–world" time–series data and the circulation models. Accordingly, the carbon isotope time–histories are providing significant constraints on, and important insights into, the performance of the Ocean General Circulation Models.

Using Corals to Assess Ocean Circulation in the Tropical Pacific

Corals, which integrate concentrations of ^{14}C from ocean waters because they feed from water throughout their lifetimes, were used to reconstruct ocean circulation patterns in the tropical Pacific. In studies conducted in collaboration with scientists from several universities (e.g., Harvard, UC Irvine, UC Berkeley), upwelling of cold water in the eastern equatorial Pacific was shown to bring low-^{14}C water to the surface at the Galapagos Islands. This water is then advected to the western Pacific warm pool (Nauru) where it mixes with



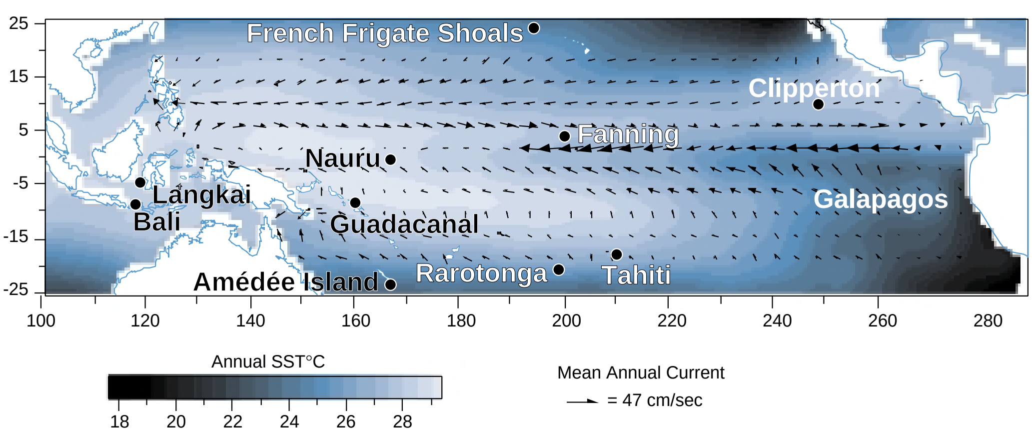
Levels of ^{14}C measured in corals obtained from sites in the equatorial Pacific are providing a detailed record of ocean circulation and upwelling events.

high ^{14}C water from the subtropics (French Frigate Shoals, Rarotonga). Carbon-14 measurements obtained from Guadalcanal are also shown on the above figure. The record from French Frigate Shoals is from the literature.

The long-term trend in the individual coral records reflects the uptake of bomb ^{14}C in the ocean and its subsequent dilution and mixing with interior water masses. This information is being used to understand global heat balance and is providing unique insights into the relationship between ocean circulation and global climate phenomena.

Radiocarbon as a chronometer and indicator of climate change

Radiocarbon measurements (^{14}C) are being used to define climate and carbon cycle variations from decades to millennia over the past 30,000 years. Carbon-14 dating provides a temporal framework for records of climate change and its relationship to ocean circulation. In collaboration with scientists from Harvard University and the University of Colorado, CAMS has extended the calibration curve that relates radiocarbon ages to calendar years by measuring ^{14}C in marine carbonates from ocean sediments that contain distinct annual layers. Until now the calibration was based on ^{14}C measurements in wood dated by tree-ring counting. New data have revealed previously undetected changes in ^{14}C concentrations that are thought to be due to the effect on the carbon cycle of climatic disturbances associated with the glacial to post-glacial transition. In particular, changes in ^{14}C concentrations that



Sea-surface temperatures (SST) and mean annual currents for the equatorial Pacific. Upwelling of cold, deep water in the eastern Pacific results in relatively cool surface waters that have correspondingly low levels of ^{14}C.

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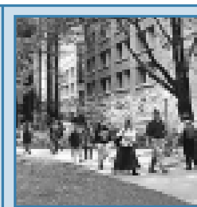
FY98–99: 30

Faculty

FY98–99: 2

CAMS University Collaborative Research Projects (UCRP) in FY 1998–99

UC Berkeley	UC Davis	UC Irvine	UC Riverside	UC San Francisco	UC Santa Cruz
					
"Development and Application of Cosmic-ray Produced ^{41}Ca in Natural Samples" *Kunihko Nishizumi, UC Berkeley; Marc Caffee, LLNL, CAMS* **"Partitioning of Oxygenate Carbon into Diesel Soot and Carbon Dioxide During Combustion"** *Robert Dibble, UC Berkeley; Bruce Buchholz, LLNL, CAMS* **"Weathering as a Control on Potential Carbon Sequestration in Soil"** *Ronald Amundson, UC Berkeley; Andrea Cook, LLNL, CAMS*	**"Application of Accelerator Mass Spectrometry in the Development of Ultra-Sensitive Protein Sequencing Methods"** *Young Moo Lee, UC Davis; John Vogel, LLNL, CAMS* **"Application of Nuclear Micro-probe Technology to Assess Present and Historical Environmental Information in Biologic and Sediment Samples from Lake Tahoe"** *John Reuter, UC Davis; Thomas Brown, LLNL, CAMS*	**"Examination of the Age of Carbon in Fine Roots"** *Susan Trumbore, UC Irvine; Andrea Cook, LLNL, CAMS*	**"Evaluating the Possible Late Pleistocene Occurrence of *Homo erectus* in Java: AMS-based Radiocarbon Dating of Tooth Enamel"** *Irv Taylor, UC Riverside; John Southon, LLNL, CAMS*	**"A PIXE-based Assay for Dermal Exposure to Hazardous Metals"** *Chris Cullander, UC San Francisco; Graham Bench, LLNL, CAMS*	**"Dating of the Santa Cruz Marine Terraces Using ^{10}Be and ^{26}Al Profiles"** *Robert Anderson, UC Santa Cruz; Robert Finkel, LLNL, CAMS*

occurred approximately 13,000 years ago correspond to the beginning of the Younger Dryas cold period — a 1,300 year return to glacial conditions in areas around the North Atlantic — and indicate that a major change in ocean circulation occurred at that time.

The Future

Through initial proof-of-principle experiments funded via our University Collaborative Research Program (UCRP) and CLCs, to the creation of extramurally-funded research programs, CAMS will continue to enable and enhance university, DOE, and LLNL research in a broad range of scientific disciplines. Establishment of the NIH Research Resource for Biomedical AMS is a testament to the evolution of individual collaborative research projects into a nationally-recognized research program. CAMS scientists, with their university colleagues, will continue to leverage such collaborations to build scientific programs that address problems in the national interest.

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Institute of Geophysics and Planetary Physics

The Institute of Geophysics and Planetary Physics (IGPP) was founded in 1946 at UC Los Angeles with a charter to further research in the earth and planetary sciences and in related fields.

The Institute is a Multi Campus Research Unit of UC, and now has branches at three UC campuses, Los Angeles, San Diego, and Riverside, and at Los Alamos and Lawrence Livermore National laboratories.

The IGPP branch at LLNL was approved by the UC Regents in 1982. IGPP-LLNL has two research centers; one emphasizes research in tectonics and geochemistry under the Earth and Environmental Sciences Directorate and the other in astrophysics under the Physics Directorate. IGPP provides a venue for studying the fundamental aspects of these fields, complementing LLNL programs that pursue applications of these disciplines in national security and energy research.

The IGPP branches at LLNL and Los Alamos facilitate relevant scientific collaborations between researchers at the UC campuses through the University Collaborative Research Program (UCRP), which provides funds to UC campus scientists for joint research projects.

Although the permanent LLNL staff assigned to IGPP is relatively small (presently about seven full-time equivalents), IGPP's research centers have become vital research organizations. This is possible because it supports a substantial group of resident postdoctoral fellows; 20 or more UCRP projects funded each year; and because IGPP hosts a variety of visitors, guests, and faculty members from many institutions. To focus attention on areas of topical interest in the geosciences and astrophysics, IGPP-LLNL hosts conferences and workshops, and also organizes frequent seminars in astrophysics and geosciences.

Lick telescope with Laser Guide Star Adaptive Optics.

Astrophysics Research Center

The goals of the Astrophysics Research Center include managing the astrophysics part of the UCRP and facilitating contacts between UC scientists and their LLNL counterparts. It also serves as the focus of astrophysics activities at LLNL by organizing the weekly astrophysics colloquium, by hosting visitors and collaborators, by editing an annual Observatory Report that covers astrophysics activities at LLNL (and is published in the *Bulletin of the American Astronomical Society*), and by providing a variety of other service functions.

Primordial Quasars and Proto Galaxies

The Astrophysics Research Center has developed a research program that exploits the traditional strengths in astrophysics at LLNL and opens new areas of study. This research ranges from smaller-scale theoretical and observational projects to large collaborative ventures.

W. van Breugel, together with graduate students C. De Breuck (LLNL, Leiden Observatory) and D. Stevens (UC Berkeley), A. Stanford (UC Davis, LLNL) H. Rottgering and G. Miley (Leiden Observatory), and C. Carilli (NRAO), discovered the most distant radio galaxy known to date, TN J0924-2201 at a redshift of $z = 5.19$. The radio galaxy was found from a sample of Ultra-Steep Spectrum sources, which was constructed using recent new radio surveys. These include the 'Faint Images of the Sky at Twenty Centimeters' (FIRST) survey at the Very Large Array, which is conducted at IGPP by Prof. R. Becker (UC Davis) and his collaborators, as well as the low frequency 'Westerbork Northern Sky Survey' (WENSS), which is conducted at Leiden Observatory by Prof. G. Miley and collaborators.

Deep near-infrared observations with the Keck I telescope showed that the source is identified with a very faint, K = 21.1 magnitude object (see Figure). Subsequent spectroscopic observations with the Keck II telescope showed a single emission line at 7530 Angstrom, which was identified as Lyman-alpha redshifted to $z = 5.19$.

Radio galaxies in the local universe are known to inhabit very massive elliptical galaxies, often at the centers of clusters of galaxies. The discovery of extremely distant radio galaxies, which are still young, allows one to investigate how such massive galaxies and galaxy clusters form.

At $z = 5.19$, the observed near-infrared K-band is at rest-frame UV wavelengths. The multi-component, irregular morphology of the galaxy suggests that it may still be in the process of forming. If one assumes that all of this UV light is due to young stars, then one derives a star formation rate of 200 solar masses per year, more than 10 times larger then in normal star-forming galaxies at $z > 5$.

The discovery of a radio galaxy at $z = 5.19$, when the Universe is less that 1 billion years old, may also pose interesting challenges to common theoretical wisdom, which assumes that luminous radio sources are powered by supermassive black holes that have grown larger in hierarchical fashion together with their host galaxies.

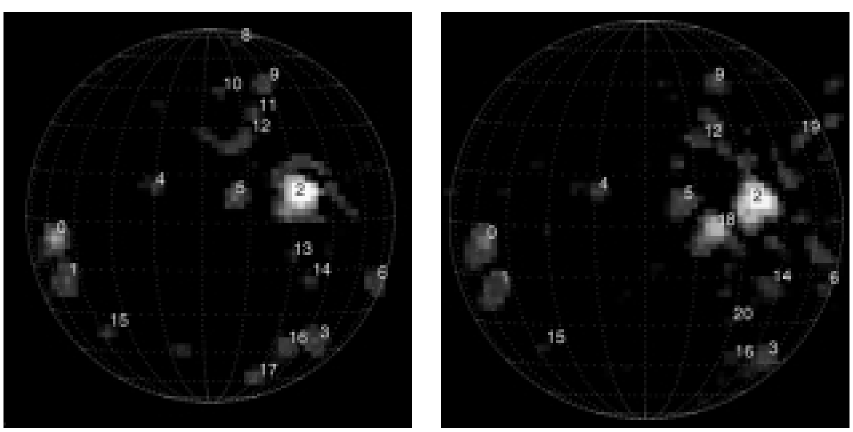
Becker (UCD), Laurent-Muehleisen (IGPP/UCD), and Gregg (UCD), in collaboration with White (STScI) and Helfand (Columbia), continued to collect and analyze new VLA observations for the FIRST survey. In 1998, ~450 hours of VLA time were awarded to expand the survey area to ~6500 sq. degrees.

Becker (UCD), Laurent-Muehleisen(IGPP/UCD), Brotherton (IGPP) and Gregg(UCD), in collaboration with White (STScI) and Helfand (Columbia), have completed a bright quasar survey over the initial 3000 sq. degrees of the FIRST survey. A paper is in preparation presenting spectra of the ~500 quasars found in the program.

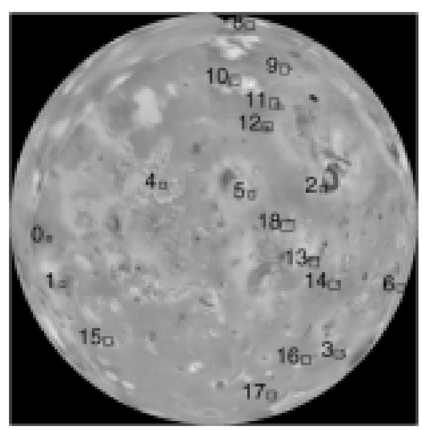
Included among the ~500 quasars were found a gravitationally lensed quasar, a binary quasar system containing a CSS radio source paired with a radio quiet quasar, and numerous Broad Absorption Line quasars.

Speckle Imaging of Titan, Io, and Neptune

Working with collaborators from UC Berkeley, NASA Ames, the Southwest Research Institute, and NASA's Jet Propulsion Laboratory (JPL), IGPP scientists are observing solar system objects at very high spatial resolution using the technique of speckle imaging. Speckle imaging uses a series of very short exposures to "freeze" the turbulence of the Earth's atmosphere. The latter, under ordinary circumstances, limits the resolution of most ground-based observations to ~0.5 arcseconds. Near-infrared observations at the 10-meter W. M. Keck Telescope of Saturn's moon Titan, Jupiter's



Near-infrared images of volcanic hotspots on the surface of Io. Observed July–August 1999 using the 10-m W.M. Keck telescope and LLNL's speckle interferometry software.



Visible-light image of Io from the Voyager spacecraft showing the location of the hotspots detected in our Keck imaging.

volcanically-active moon Io (see figure on page 16), and Neptune were obtained in October 1997 and July-August 1998. The speckle imaging technique yields spatial resolution near the diffraction-limit of the telescope (0.04 arcseconds at a wavelength of 2 microns), a factor of more than 10 improvement over conventional ground-based images.

The MACHO Project

The MACHO (MAssive Compact Halo Objects) Project is an experimental search for the dark matter which makes up at least 90% of the mass of our galaxy. The project was initiated at LLNL and involves collaborators from Mt. Stromlo Observatory (Australia), Notre Dame, University of Washington, UC San Diego, McMaster University, Oxford University, and the European Southern Observatory (Chile).

The MACHO Project has been monitoring sky fields in the Large and Small Magellanic Clouds (satellite galaxies of the Milky Way) as well as fields toward the center of the Milky Way. IGPP searches for the transient brightening of a background star when a massive compact object passes near the line of sight to the star due to the gravitational field of the object acting as a lens. This effect, called microlensing, can reveal the existence of a massive object even if it does not generate light of its own. The Project has accumulated almost 6 TBytes of image data and about 600 Gbytes of photometry on about 70 million stars. Data are reduced in near real time, and microlensing events are often identified well before their peak. The Project sends out alert announcements to the world, which are also posted on its web site (http://darkstar.astro.washington.edu). These alert announcements are used by groups throughout the world to search for extra-solar system planets and to study ongoing microlensing events in detail.

Over 350 microlensing events have been recorded. Analysis of these events shows that planets and brown dwarfs are not significant components of the dark matter in our own galaxy, but that ancient white dwarfs might be.

Searching for Asteroids

Asteroids that have close approaches to the earth are a potential hazard to life, as their impacts have caused mass extinctions in the past. It is therefore important to detect these objects and to understand their orbits.

IGPP's Kem Cook, working with Chris Stubbs of the University of Washington and Ted Bowell of Lowell Observatory, have completed an innovative 2048- x 4096-pixel scanning CCD camera, which operates on a Schmidt telescope on Anderson Mesa in Arizona. This system is the heart of the Lowell Observatory Near-Earth Object Survey (LONEOS), and allows about 1000 square degrees of the sky per night to be triple-scanned to detect near-Earth objects through their rapid apparent motion.

The LONEOS system began taking data with the newly refurbished Schmidt telescope in 1997. It was decided, however, that the corrector and field flattener that were being used needed to be refabricated. These elements were reinstalled during the winter of 1998, and the system has been operational for most 1998. It discovered its first Near Earth Object (1998 MQ) six more in 1998 and 14 in all of 1999.

Laser Guide Star Adaptive Optics (AO)

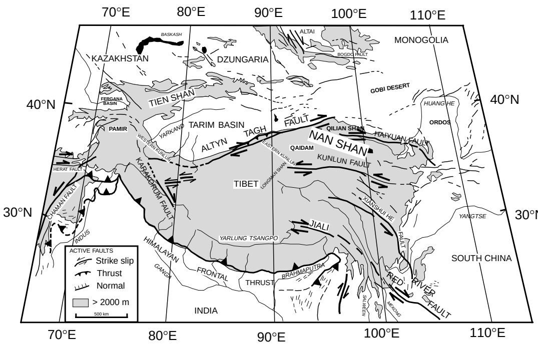
Working with LLNL scientists and UC faculty, IGPP staff are developing laser guide stars for astronomical adaptive optics. The goal is to improve the angular resolution achieved at ground-based observatories by removing the blurring due to turbulence in the Earth's atmosphere. If it is successful, the angular resolution at major observatories might be improved by factors of 5–50.

A 20-W dye laser and an adaptive optics system (both developed at LLNL) have been installed on UC's Lick Observatory 3-m Shane telescope. The laser is based on technology developed for the LLNL Atomic Vapor Laser Isotope Separation (AVLIS) program and produces an eighth magnitude artificial guide star, sufficient for adaptive optics correction of the 3-m telescope at wavelengths of 1–2 µm.

During 1998–1999, effort focused on refining the system, improving its performance and reliability. The first laser guide star science observations were conducted in November 1998. This system was used to develop the calibration and observation techniques that all other laser guide star AO systems will need as they become operational on large telescopes.

The adaptive optics system also demonstrates excellent performance using bright natural guide stars as references. Natural-guide-star science programs studying young stellar objects, binary stars, and the outer planets are being carried out in collaboration with faculty and students at UC Los Angeles and UC Berkeley. A systematic search has been carried out for stellar companions to the stars known to have planets orbiting them. This is an attempt to see if perturbations by previously unknown stellar companions can explain the bizarre planetary systems recently discovered. Observations of the outer gas giant planets Neptune and Uranus are being used to develop models of their atmospheric structure and composition.

LLNL scientists and engineers also played an important role in building the wavefront controller (part of an adaptive optics system) and laser guide star system for the 10-m W.M. Keck telescope, which was shipped to the Keck observatory for integration into a Keck-built optics bench in the spring of 1998.



Tectonic map of central Asia. The regions with elevations above 2000 m – largely the Tibetan Plateau – are shown in light gray. Shortening an uplift associated with thrust faulting is active along the Himalayan Front, the Pamir, the Tien Shan and the Nan Shan. The great strikes slips of Asia include the Altyn Tagh, the Kunlun, the Haiyuan, the Karakorum, the Jiali and the Xianshuhe Faults. IGPP researchers are currently working on the Altyn Tagh Fault which bounds the northern edge of the Tibetan plateau. This fault allows the eastward propagation of Tibet, and likely drives the thrust faulting in the Nan Shan.

Center for Geosciences

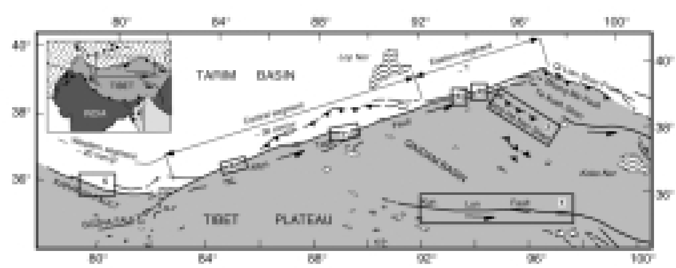
The Geosciences Research Center was formed to promote collaborative research in the geosciences among LLNL, the various UC campuses, and other scientific organizations. LLNL's mission-oriented programs contain expertise in many geoscience disciplines. IGPP draws upon these capabilities and acts as a focal point for research in the more fundamental aspects of the earth sciences. The Center's research emphasis is on the physics and geochemistry of the solid Earth, seismology, experimental petrology, mineral physics, environmental geochemistry, hydrology, tectonics, and active tectonics.

The current research is focused around two major projects: experimental determination of the partitioning of trace elements between minerals, fluids, and melts relevant to subduction zones and mid-ocean ridges, and the Cenozoic and active tectonics of the Indo-Asian collision. The program in Asian tectonics considers both the long-term evolution of the Tibetan Plateau and Himalaya mountains, and also the active tectonics of the region.

Research Highlights

Geospeedometry: Dating Tectonic Deformation

The goal of this project is to develop and apply cosmogenic dating methods to better constrain rates of tectonic deformation across active faults and folds in the collision zone between India and Asia. Active faulting and seismicity show that deformation in Central Asia is partitioned between thrust faulting in mountain belts and lateral displacement along great strike-slip faults. The extent to which deformation is localized along these faults as opposed to homogeneously distributed throughout Asia is critically dependent upon the rates of slip, and bears upon the more general question of how the Earth's lithosphere deforms. LLNL, working with UC Los Angeles, the Institut de Physique du Globe de Paris, and the Chinese Seismological Bureau, is investigating sites along the Tibet-Tarim Basin boundary, which is defined by the Altyn Tagh Fault System (ATF). The ATF runs along the



Generalized tectonic map of northern Tibet (area shown in box on inset map of Asia) indicating the areas under investigation in this project. IGPP's Center for Geosciences is attempting to determine rates of strike-slip movement along the Kunlun Fault (1), and the Aksay (3), Subei (4), Karakax Valley (5), Tura (6) and Shur Kholi (7) segments of the Altyn Tagh Fault and uplift along the borders of the Tang He Nan Shan (7).

northern edge of the Tibet-Qinghai highlands for nearly 2000 km, merging with various thrust and other strike-slip systems at its eastern and western termini. Eastward propagation of the ATF may be the primary mechanism by which the northern part of the plateau has grown.

Mineralogy of the Upper Mantle, and Partial Melting Depths and Temperatures of Oceanic Basalts

The ocean floor is composed almost entirely of basalt, a rock composition formed by partially melting the Earth's upper mantle. To understand the evolution of Earth, it is critical to know the composition of Earth's mantle as well as the depths and temperatures at which partial melting occurs. As a melting product of this upper mantle, basalt acts as one of our only chemical probes of this region. LLNL scientists are comparing basaltic lavas from Hawaii and the East Pacific Rise in an attempt to better understand the mantle source chemistry and melting regimes in these regions. Lavas from these localities are different. The Hawaiian magmas are formed by partial melting above a superadiabatic thermal upwelling, or a 'mantle plume.' The East Pacific Rise, in contrast, is a passive spreading center; melting occurs when mantle of normal temperature rises to fill the void left by the separation of oceanic lithosphere. Hawaii is the result of a thermal upwelling, and it is expected that partial melting occurs at relatively high pressures (P) and temperatures (T), and that Hawaiian lavas tap a deeper mantle source, compared to East Pacific Rise lavas. Modeling of the melting process, constrained by experimental phase equilibria, indicates that melting below the Hawaiian islands began at depths of 200-400 km, while the East Pacific Rise lavas require melting depths of only 90-120 km. The full range of basalt compositions at both sites requires only a 2% variation in the chemistry of the source region demonstrating the importance of melting conditions on the formation of basaltic lavas.

The Geochemical Earth Reference Model—GERM

Understanding the global chemical dynamics of the Earth requires a simple but comprehensive set of data on chemical inventories of the major Earth reservoirs and the fluxes between them. Ideally, such a data set could be formulated in terms of a reference model consisting of direct measurements that represent a very close approximation to the actual compositions and exchange rates. Unfortunately, such a model would be impossible to establish for the Earth because most of our planet is not accessible to direct observation. Nevertheless, even an imperfect chemical "reference" model for the Earth would be of enormous utility for Earth scientists.

The development of the Geochemical Earth Reference Model (GERM) began with an initial workshop in Lyon, France, in 1996. Since then, the GERM effort has continued, fostered by workshops and special sessions at professional meetings. The actual model is being developed in an open community forum on the World Wide Web hosted at Lawrence Livermore National Laboratory (http://www.es.llnl.gov/germ/).

The Future

The IGPP has successfully established, or assisted in the establishment of a large and exciting portfolio of scientific collaborations between LLNL scientific staff and researchers at universities. In the next few years, IGPP expects to augment this program with exciting new collaborations, which are larger in scale. For example, the Institute expects to exploit the new 3-dimensional stellar evolution code in many collaborations with university students.

Institute of Geophysics and Planetary Physics Staff FY98–99

Director
Charles Alcock

Head of Astrophysics Branch
Kem Cook

Head of Geosciences Branch
Rick Ryerson

Scientific Staff
Robert Becker
Seran Gibbard
Geza Kovacs
Bruce Macintosh
Stuart Marshall
Wil van Breugel
Adam Stanford

External Researchers
FY98–99: 150 (worldwide)

Postdoctoral Staff
Nahum Arav
Mike Brotherton
Jian Ge
Michael Gregg
Mark Hammergren
Bradford Holden
Mark Lacy
Sally Laurent-Muehleisen
Dante Minniti
Piotr Popowski
Hein Tran

Students
FY98–99: 45

Faculty
FY98–99: 1

IGPP University Collaborative Research Projects (UCRP) in FY 1998-99

UC Berkeley

"Speckle and Adaptive Optics Imaging of Planets and Satellites"
Imke De Pater, UC Berkeley; Seran Gibbard, LLNL, URP

"Recurrence, Interaction, and Source Processes of Small Characteristic Earthquakes"
Thomas V. McEvilly, UC Berkeley; Lawrence Hutchings, LLNL, Geophysics & Global Security

"3D Modeling of Structure in D″"
Barbara Romanowicz, UC Berkeley; Shawn Larsen, LLNL, Computer Systems & Applications Division

"A Phonon-Mediated Particle Detector for Observational Cosmology and Gamma-Ray Astronomy"
Bernard Sadoulet, UC Berkeley; Carl A. Mears, LLNL, V Division

"A Search for Red Quasars: The Radio-Loud Quasar Population at $z \geq 3$"
Hyron Spinrad, UC Berkeley; Wil van Breugel, LLNL, IGPP

"Radiocarbon Record of Ventilation Changes along the California Margin"
B. Lynn Ingram, UC Berkeley; John Southon, LLNL, CAMS

"Magnetic Fields in Supernova Remnants and the Development of Adaptive Mesh Refinement Magneto-hydrodynamics"
Christopher F. McKee, UC Berkeley; Richard I. Klein, LLNL, A Program

"Deformation of Olivine: Comparison of Predictions with Experiments"
H.-R. Wenk, UC Berkeley; W. Durham/C. Mailhiot, LLNL, Geophysics & Global Security

"Detection of Occultations"
John A. Rice, UC Berkeley; Charles R. Alcock, LLNL, Physics Admin.

"Ultra-High Pressure Melting Studies"
Raymond Jeanloz, UC Berkeley; Jagannadham Akella, LLNL, Geophysics & Global Security

"Cosmogenic Nuclide Systematics in Olivine and Calcite"
Kunihiko Nishiizumi, UC Berkeley; Robert C. Finkel, LLNL, Geosciences & Environmental Technology

UC Los Angeles

"Investigation of the Age and Slip Rate of the Karakorum Fault in Western Tibet"
An Yin, UC Los Angeles; Rick Ryerson LLNL, Geophysics & Global Security

"Molten Crust Beneath Tibet?"
T. Mark Harrison, UC Los Angeles; Rick Ryerson, LLNL, Geophysics & Global Security

"Application of the UC-LLNL Regional Climate System Model to the Malibu Creek Watershed"
John A. Dracup, UC Los Angeles; Norman Miller, LLNL, Atmospheric & Ecological Sciences

"High-Resolution Study of Inner-Core Rotation"
John E. Vidale, UC Los Angeles; Doug A. Dodge

"Oxygen Isotope Exchange during Dynamic Crystallization: Constraints on Processing of Pre-Solar Components in CAIs"
Laurie Leshin, UC Los Angeles; Rick Ryerson, LLNL, Geophysics & Global Security

"Initiation Age and Rate of E-W Extension in Northern Tibet: Implications for the Dynamic Cause of Tibetan Uplift"
An Yin, UC Los Angeles; Rick Ryerson, LLNL, Geophysics & Global Security

"The Isotopic and Chemical Composition of Carbonaceous Matter Produced by Serpentinization—An Exploration of a Potential Fischer-Tropsch Type Reaction Process"
Stephen J. Mojzsis, UC Los Angeles; Kevin G. Knauss, LLNL, Geosciences & Environmental Technology

"Experimental Mineral Diffusion Studies: Constraints on the Thermal Histories of Meteorites and Planetary Formation Timescales"
Thomas La Tourrette, UC Los Angeles; Ian D. Hutcheon, LLNL, Isotope Sciences Division

"Collective Absorption Properties of Neutrinos in Supernovae"
John M. Dawson, UC Los Angeles; Hollis E. Dalhed, LLNL, A Division

UC Santa Cruz

"Controls of Uranium Groundwater Chemistry Constrained by AMS ^{14}C and 36 Cl"
Dr. James B. Gill, UC Santa Cruz; Dr. Gregory Nimz, LLNL, Geosciences & Environmental Technology

"Experimental Constraints on the Chemical Evolution of Icy Satellites"
Quentin Williams, UC Santa Cruz; Rick Ryerson, LLNL, Geophysics & Global Security

"Source Effects on Regional Seismic Discriminant Measurements"
Thorne Lay, UC Santa Cruz; William R. Walter, LLNL, Geophysics & Global Security

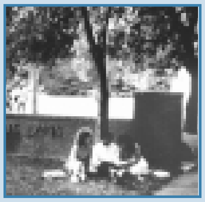
"Collaborative Seismic Investigation of South American Tectosphere"
Justin Revenaugh, UC Santa Cruz; Stephen C. Myers, LLNL, Geophysics & Global Security

"Seismic Velocity Structure of the North and Central African Lithosphere from Upper Mantle P, PP, S, and SS Waveform Modeling"
Susan Y. Schwartz, UC Santa Cruz; Arthur Rodgers

"Cosmogenic Exposure Age Dating of Glacial Deposits in the Cordellero Blanca, Peru: Toward a Detailed Record of Southern Tropical Climate Change"
Robert S. Anderson, UC Santa Cruz; Daniel L. Farber, LLNL, Geophysics & Global Security

IGPP University Collaborative Research Projects (UCRP) in FY 1998-99

UC Davis



"A VLA Survey of the Sky at 1400 MHz"
Robert H. Becker, UC Davis; Wil van Breugel, LLNL, IGPP

"Integrating Postseismic Relaxation into Crustal Stress Evolution Models"
Louise Kellogg, UC Davis; William Foxall, LLNL, Geophysics & Global Security

"A Radio Selected Sample of Active Galactic Nuclei"
Robert H. Becker, UC Davis; Wil van Breugel, LLNL, IGPP

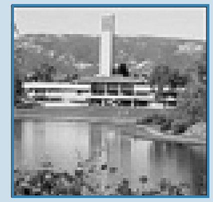
UC Riverside

"Timing of Late Quaternary Glaciation in the Hunza Valley, Karakoram Mountains, Northern Pakistan"
Lewis A. Owen, UC Riverside; Robert C. Finkel, LLNL, Geosciences & Environmental Technology

UC San Diego

"A Full Determination of the MACHO Microlensing Detection Efficiency toward the LMC, SMC, and Bulge"
Kim Griest, UC San Diego; Charles R. Alcock, LLNL, Physics Admin.

UC Santa Barbara



"Noble Gases Dissolved in Groundwater from the Northern United States: Tracers for Paleoclimate and Groundwater Flow"
Jordan F. Clark, UC Santa Barbara; G. Bryant Hudson, LLNL, Glenn T. Seaborg Institute of Transactinium Sciences

"Dynamic Earthquake Rupture Simulation on Dipping Faults"
Ralph J. Archuleta, UC Santa Barbara; William Foxall, LLNL, Geophysics & Global Security

For further information contact:

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URL: http://www.llnl.gov/urp/IGPP/

Institute for Laser Science and Applications

The mission of the Institute for Laser Science and Applications (ILSA) is to strengthen the research interactions between LLNL and the academic community in the field of high power lasers and their applications.

The Institute for Laser Science and Applications (ILSA) facilitates training and research for university students and faculty in areas critical to Department of Energy (DOE) needs in laser interactions with matter and in advanced laser technologies. The primary objective of the Institute is to benefit DOE programs by attracting students to the fields of laser science and high-energy-density physics. In particular, ILSA is training the next generation of laser-matter interaction scientists who will use the National Ignition Facility (NIF) when it is completed. As part of this mission, the Institute oversees access for students and faculty members to existing LLNL laser experimental facilities and diagnostics.

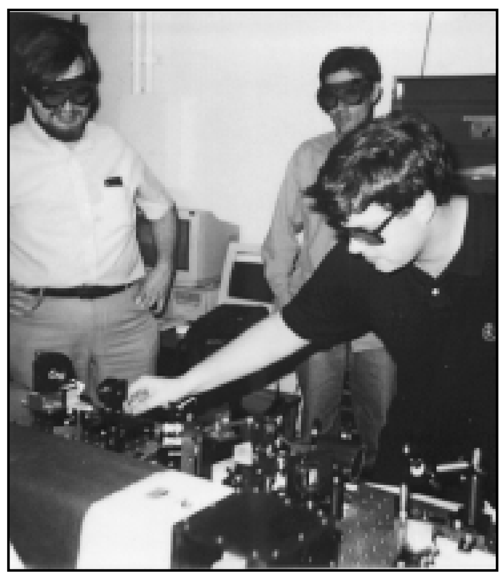
ILSA Research Highlights

Particle-Photon Interaction Physics

A joint research group including ILSA, UC Los Angeles and UC Davis conducts theoretical, experimental, and computational research on Free Electron Lasers (FEL), laser acceleration of electrons and protons to higher energies, and nonlinear Compton scattering. In these experiments, laser pulses as short as a millionth of a billionth of a second, but with peak powers exceeding the entire power generated in the U.S., collide with relativistic electron beams to produce bright x-ray flashes (a process called Compton Scattering). The unique characteristics of this new x-ray source, including its intensity, ultrashort duration, compactness, and tunability, make it attractive for a number of exciting applications, such as advanced biomedical imaging, ultrafast material science and laboratory astrophysics. X-ray protein crystallography, using recombinant DNA technology and the Compton Light Advanced Source (CLAS), will help discover the structure and function of proteins, and support the design of entire classes of new drugs.

Parametric Instabilities in Laser Plasmas

The interaction of a high-intensity laser beam with a plasma is a very complex activity, dominated by nonlinear processes. Among these is the coupling through parametric processes, where three or more waves are involved. Parametric instabilities, so called because of analogy with parametric amplifiers, are extremely important in coupling the energy from the laser into other waves in the plasma. The study of these instabilities is crucial in the context of laser fusion. Many aspects of the interaction remain unexplained. The primary instabilities are



Students from UC Davis Department of Applied Science (Anthony Troha, James VanMeter and Eric Landahl) adjust the short-pulse high-intensity laser used for Compton scattering experiments.

Stimulated Brillouin Scattering (SBS), Stimulated Raman Scattering (SRS), and filamentation. ILSA has developed an extensive research program in this area, both experimental and theoretical, in collaboration with Ecole Polytechnique in France, the University of Alberta, Canada, and UC Los Angeles.

Of current interest is the modification of the optical characteristics of a laser beam by a plasma, and its effect on the study of parametric instabilities. It is believed that the neglected forward SBS can play an important role in smoothing the laser beam as it traverses the plasma. If proven, this could have a significant impact on the interpretation of laser-plasma interactions and a unique way to interpret data from experiments. A theoretical study was performed using specially developed computer codes, an approach that has a tremendous potential to study waves in plasmas on time scales that are realistic in relation to available experimental data.

Relativistic Plasma Physics

The development over the last decade of high-power ultra-short-pulse lasers, with pulse lengths less than a thousandth of a billionth of a second, has created a completely new field of relativistic laser-matter interaction physics. Several large-scale laser facilities around the world are now capable of producing focused laser intensities greater than 10^{19} Watts/cm^2 on target. At such intensities, the electric field of the laser will directly accelerate free electrons in the target material to highly relativistic energies. The relativistic hot, dense plasma generated is a rich source of highly energetic (several MeV) electrons, ions, and gamma-rays. Particle energies are sufficient to instigate numerous types of nuclear reactions, as well as relativistic processes such as electron-positron pair production. In collaboration with UC Los Angeles, ILSA is currently performing three-dimensional particle-in-cell (PIC) computer simulations of the propagation of an intense laser pulse, through an underdense plasma, where a number of wave-wave interaction processes are important in the relativistic regime.

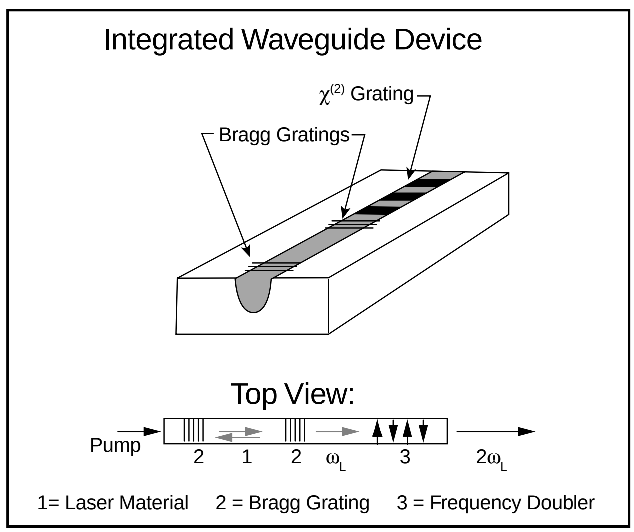
X-ray Lasers and Imaging Applications

Historically, x-ray lasers have been used to image biological specimens with high resolution and to diagnose high-density plasmas. To extend these applications to higher resolution and densities, it will be necessary to produce shorter-wavelength and shorter-pulse-duration x-ray lasers. ILSA researchers in collaboration with UC Berkeley and UC Davis, are performing experiments that take advantage of short pulse (1-5 ps) optical lasers to pump transient inversion x-ray lasers. These schemes offer the potential for high x-ray laser output with low input optical pump energy (~10J). Their 5-10 ps pulse width also make them ideal for probing high-density plasmas where image blurring due to plasma motion is an issue.

ILSA is also investigating the use of high-power ultrashort-pulse (20-50 fs) optical lasers to produce an new class of x-ray lasers. These x-ray lasers rely on inner-shell electron transitions, for example 2p-1s in carbon, to achieve short wavelengths with low pumping energies. The ultrashort-pulse pump is necessary to generate a short burst of x-rays that ionize an inner-shell electron (e.g., 1s in carbon) to produce the population density inversion necessary for laser operation. The goal is to produce a carbon x-ray laser that can be used to image live biological specimens with high resolution (100 Å).

Waveguide Lasers and Devices

ILSA's research program is also addressing new lasers and optical devices that are based on waveguide or fiber technology in collaboration with UC Davis. Such devices, which include fiber lasers, fiber and waveguide amplifiers, fiber Bragg gratings, and nonlinear optical switches, are currently revolutionizing the communications, sensor and laser industries.



Schematic of a Channel waveguide showing the different components forming a laser cavity, and its frequency converter, within the waveguide itself.

Falgun Patel, a student at the UC Davis Department of Applied Sciences, showing output of Neodymum-doped phosphate glass waveguide laser.

In the past year, researchers have been working on rare-earth doped phosphate glasses, in which channel waveguides are fabricated using photolithography and electric-field assisted Ag ion diffusion. We have demonstrated a diode-pumped Nd-phosphate channel waveguide laser and are currently studying other lasant ions such as Yb.

ILSA is also investigating the possible fabrication of other optical elements such as Bragg gratings or electro-optic modulators in these new waveguide materials. The objective is to combine these different functionalities into novel optical laser devices. These new laser sources offer the potential of compact, efficient, high-brightness lasers for applications in telecommunications, sensors and industrial applications, as well as master oscillators for high power laser amplifier systems.

In the Bragg grating project, ILSA researchers are studying how Bragg gratings can be optically written in phosphate glasses. The approach is to use Ce and Tm doping to enhance the photosensitivity of the phosphate glass.

ILSA has also started a project on electric field poling of these same phosphate glasses. The objective of this work is to introduce a second-order nonlinearity on the glass, thereby enabling the fabrication of frequency doubled waveguide laser devices.

High-Energy-Density Plasmas

The interest in high-energy-density plasmas is motivated by both theoretical and applied interest. There is great difficulty in producing matter that is at once hot and dense, as the high pressures generated act to rapidly expand the matter, making these plasma extremely short lived. Theoretically, hot dense matter represents an extreme state that exists naturally in the cores of stars, reaching 100 times solid density and temperatures of 10 million Kelvin. This challenges standard concepts of how an ion behaves in these plasmas, since the orbiting electrons of the ions are severely altered by their surroundings. Further, the workings of nuclear weapons and the creation of inertial confinement fusion are applications that access the high-energy-density regime. This leads to keen applied interest in the results of experiments on high-energy-density matter. Researchers from UC Berkeley are collaborating with ILSA on this project.

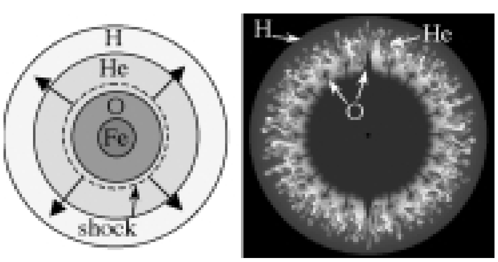
Laboratory Astrophysics

The Center for Laboratory Astrophysics in ILSA is using the Omega laser at the University of Rochester to study hydrodynamics (the flow of gases or fluids) in supernovae (SNe). Supernovae, the explosion of massive stars, shape the evolution and chemical composition of our galaxy, solar system, and Earth. However, puzzling observations of radioactive material ejected from the famous SN 1987A suggest that large-scale hydrodynamic mixing of the star’s material occurred during that explosion. Hydrodynamic mixing is similar in SNe and in laser fusion experiments to be done at the National Ignition Facility (NIF) at LLNL, making SN experiments of interest to both LLNL workers and university astrophysicists.

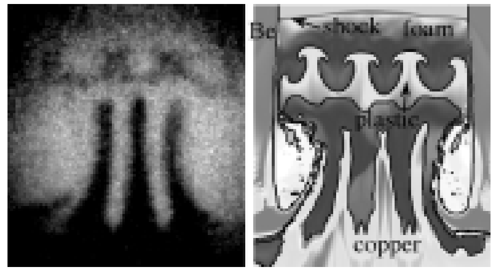
The figure on the following page shows how an SN occurs. As seen in the left panel, the initial star has several layers of material: a very dense iron core (Fe), a less dense oxygen layer (O), a still less dense Helium layer (He), and a tenuous hydrogen envelope (H). In the explosion, a strong shock emerges from the core and expands outward through the star. Because the shock front is distorted by the misshapen core and by dense clumps in the O layer, it oscillates and can trigger hydrodynamic mixing as it crosses the O-He and He-H interfaces. The right panel shows such mixing, from a computer simulation of SN 1987A using the astrophysics code PROMETHEUS. At the O-He interface, ‘spikes’ of dense O (shaded dark) penetrate well into the He layer, while ‘bubbles’ of the lighter He move into the O layer. Similarly, spikes of He and bubbles of H appear at the He-H interface.

Data and the computer figure above shows results of the laser experiment at Omega. The left panel shows an x-ray photograph of the target after it was hit by the laser beams. The right panel shows a computer simulation of the experiment using the LLNL code CALE. The target has three layers of material: dense copper (Cu), less dense plastic, and low-density foam. A beryllium shock tube (Be) encloses the target; it is transparent in the data but is shown in the simulation. The laser beams heat the Cu, sending a strong shock through the target, from top to bottom in the data. The shock turns the target into hot, star-like plasma and triggers hydrodynamic mixing at the copper-plastic and plastic-foam interfaces. The long, dark fingers in the data are spikes of Cu penetrating the plastic; the short gray fingers are spikes of plastic penetrating the foam. The plastic spikes line up with the plastic bubbles at the Cu-plastic interface, and not with the Cu spikes. This happens by design, because the shock crosses a carefully machined ripple at the Cu-plastic interface, making it oscillate once before hitting the plastic-foam interface, where it imprints an 'inverted' ripple. Thus, the data produced clear evidence that an oscillating shock was present, and that such shocks can produce significant hydrodynamic mixing in multiple-layer plasmas, a result of interest to fusion and SN researchers.

In addition to the University of Rochester, ILSA collaborators on this project include the University of Michigan, University of Arizona, University of Colorado and Rice University.



Supernova explosion. Left: schematic of shock expanding through structure of initial star. Right: hydrodynamic mixing in computer simulation of SN1987 A using PROMETHEUS computer code.



Data (left) and computer simulation using CALE code (right) of an astrophysical hydrodynamics experiment at the Omega laser. Long fingers of dense Cu penetrate a less dense plastic layer, while shorter fingers of plastic penetrate a low-density foam layer.

Recreating Planetary Cores in the Laboratory

Most planetary models are constructed from space probe data (gravitational moments, magnetic fields), and typically these models do not include the most sophisticated equations of state, electronic properties, or chemistry. ILSA is obtaining EOS and transport data for elements and compounds found in large planets at pressures relevant to planetary cores to provide rigid constraints for these models. In collaboration with UC Berkeley, a series of experiments has been started to measure the shock-wave equations of state of water, a primary constituent of Neptune, Uranus, and the Jovian moon Europa; iron, critical for understanding the Earth's core; and carbon which is also a constituent of the large gas planets as well as white dwarfs.

Preliminary measurements for water extend to pressures up to 500 GPa (5 Mbar). The highest pressure reached in conventional single-shock measurements of water is 80 GPa (obtained using a two-stage light-gas gun), and there is one data point at approximately 1400 GPa published by Russian researchers utilizing a nuclear explosion. Our laser experiments were designed to produce data in the region around from 100 to 500 GPa where an ionic-to-electronic transition is predicted to occur and where there are no data currently available.

"As a graduate student at ILSA, I have benefited from both the unique facilities at LLNL and a continuing close relationship with my academic department at UC Davis. In addition, ILSA support of our group's research has led to new results and applications of my work."

Eric Landahl, 4th year graduate student, UC Davis Dept. of Applied Science, Student Employee, LLNL

Institute for Laser Science and Applications Staff FY98–99

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FY98–99: 15

Students
FY98–99: 18

ILSA measures the reflectivity and the equation of state, impedance-matched to aluminum, with a VISAR interferometer. This optical technique requires the shock front to reflect light like a mirror. By measuring the Doppler shift of the light reflected from the moving shock front, researchers determine its velocity. By measuring the change in reflectance between the stationary aluminum plate and the moving shock front, the high pressure reflectivity can be obtained.

These data will help unravel the mysteries of the space probe magnetic field data from Uranus and Neptune. At high enough shock pressure, the electronic conducting states are likely generated simply by ionization, but at the onset of the transition ,the temperatures are thought to be low enough that the transition occurs through a shock-induced change in molecular structure (breaking and rearrangement of bonds).

Advanced Computer Modeling

A new type of numerical model has been developed that can be applied to a range of plasma conditions, where existing models fail. Grid and Particle Hydrodynamics (GaPH) is a mixture of models used at extremes; a mixture of the powerful but prohibitively expensive Particle-In-Cell kinetic model and the multiple fluid (thus collision dominated) Lagrangian Hydrodynamics model.

Essentially, GaPH is a “smart” Particle-In-Cell algorithm where each finite size particle is an element of fluid. GaPH advances in stages. The fluid elements evolve and are cast into even more new particles. Particles may then interact with each other or external forces. Subsequently, particles are merged to remove redundancy in representation. The competition between new and merging particle formation gives GaPH the desirable trait of being self-adaptive. When flows become complex, merging does not occur. Conversely, simple flows can be captured by a few particles.

This project has resulted in the development of a completely new class of algorithms that can solve the equations describing a system (matter, plasma, etc.) under parameter regimes that could not have been done before.

Optical Laser Damage

The interaction of intense laser light with transparent dielectric materials is a fundamental physics problem that, with the rapid development of even more powerful lasers, is becoming increasingly important in various science and technology applications. Of particular interest is the study of KDP, a nonlinear crystal used to double and triple the frequency of the laser light. Since large quantities of this crystal will be used in the National Ignition Facility (NIF), the understanding of the damage mechanism is extremely important.

This research program has three aims: (1) identify damage precursors, (2) understand the role of laser induced heating in damage and conditioning (pre-exposure), and (3) investigate the electronic structure of defects that couple the laser energy to the lattice. To achieve its purpose, ILSA and partners California State University – Northridge and West Virginia University, employed a combination of spectroscopic micro-imaging and micro-beam analytical tools to identify precursors to damage, spectroscopically probe the thermal and electronic structure of the defects both below and above the threshold for laser damage, and determine the effects of laser conditioning. Optically active electronic defect clusters were imaged for the first time in the bulk of a dielectric material in KDP crystals. The experimental results show that the concentration of these clusters depended on the crystal growth method, speed of growth and crystal sector.

The Future

Over the course of the next two to three years, ILSA will focus on four specific goals: (1) to develop a laser-based x-ray source for application to protein crystallography in support of the next phase of the Human Genome Program; (2) to coordi-

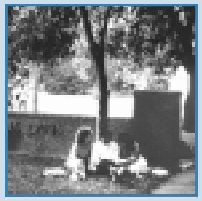
ILSA University Collaborative Research Projects (UCRP) in FY 1998-99

UC Berkeley

"Advanced X-ray Diagnostics"
Roger Falcone, UC Berkeley; Richard Lee, LLNL, Physics

"Quasi-Static Investigations of High-Pressure, High-Temperature Dynamic Experiments"
Raymond Jeanloz, UC Berkeley; Robert Cauble, LLNL, Physics

UC Davis



"Preparation and Characterization of Glasses for Fiber Bragg Gratings"
Subhash Risbud, UC Davis; Denise Krol, LLNL, C&MS

"Silicon Micromachined Scanner for Optical Coherence Tomography"
Jonathan Heritage, UC Davis; Matthew Everett, LLNL, Laser Programs

"Optically Induced Bragg Gratings in Phosphate Glasses"
Subhash Risbud, UC Davis; Denise Krol, LLNL, C&MS

"Computational and Experimental Development of a Compton X-ray Source"
Neville Luhmann, Jr., UC Davis; Hector A. Baldis, LLNL, URP

"Thomson Scattering Measurements of Non-Maxwellian Distributions in Laser Heated Plasmas"
John DeGroot, UC Davis; Siegfried Glenzer, LLNL, Laser Programs

UC Los Angeles

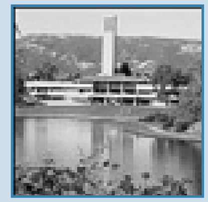
"Critical Surface Interaction Plasma Physics Experiments"
Peter Cheung, UC Los Angeles; Peter Young, LLNL, Physics

"Plasma Compression of Chirped Electromagnetic Pulses"
Peter Cheung, UC Los Angeles; Peter Young, LLNL, Physics

"Development of RF Photoinjector Physics and Technology"
James Rosenzweig, UC Los Angeles; Gregory Le Sage, LLNL, Electronics Engineering

"Three-dimensional Particle-in-Cell Simulations of Intense Lasers Propagating in Underdense Plasmas Near Quarter Critical Density"
Warren Mori,UC Los Angeles; Chris Decker, LLNL, D&NT

UC Santa Barbara



"Short-Pulsed Laser Vaporization of Metals"
Ted Bennett, UC Santa Barbara; Mark Havstad, LLNL, Mechanical Engineering

nate the use of existing laser resources at LLNL and thereby foster an enhanced participation of University researchers; (3) to double the number of students working on ILSA projects; (4) to establish a laser laboratory at UC Davis to attract students to careers in laser science and applications.

Through the accomplishment of these goals, ILSA will continue to develop and implement a program designed to support the core mission requirements of the Laboratory and DOE, especially in the recruitment and training of the future scientific talent essential to the long term operation of NIF.

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ILSA.home.html

Institute for Scientific Computing Research

The mission of ISCR is to foster collaborations between Lawrence Livermore National Laboratory and academic researchers in the areas of scientific computing, computer science, and computational mathematics.

The Institute for Scientific Computing Research (ISCR) was established in 1986 to assist in keeping LLNL at the leading edge of computational science and engineering by complementing permanent staff with strategic collaborators from the nation's universities, and by cultivating the next generation of interdisciplinary laboratory leaders through immersive research experiences. These efforts have proven central to large-scale scientific simulations for DOE's stockpile stewardship program, and in particular for the Accelerated Strategic Computing Initiative (ASCI) program.

The ISCR hosts a large number of student guests who spend summers working at the Laboratory. Many of these are graduate students who are later hired by LLNL and other DOE labs. In this way, the ISCR plays an essential role in DOE recruitment efforts. The ISCR also has substantial collaborations with University of California (UC) campuses.

Large-scale scientific computation, and all of the disciplines that support and help to validate it, have been placed at the focus of LLNL by the ASCI. A major goal of ASCI is to replace the full-scale experiments that are a part of the traditional maintenance and readiness certification of nuclear devices with computational simulations. Whereas the majority of design efforts can be done in two-dimensional axisymmetry, evaluation of failure modes is fully three-dimensional, requiring immensely more computational power and algorithmic sophistication. In addition, the results of simulations must be made more reliable for extrapolation beyond experimental data, whereas in the past simulations have served primarily for interpolation between experimental data. The Laboratory operates the computer with the highest peak performance in the world and has undertaken some of the largest and most compute-intensive simulations ever performed. However, computers at architectural extremes are notoriously difficult to use efficiently, and even successes (such as the Laboratory's two Bell Prizes awarded in November 1999) only point out the need for much better ways of interacting with the results of large-scale simulations.

Advances in scientific computing research have therefore never been more vital to the core missions of the Laboratory and DOE than at present. Computational science is evolving so rapidly along every one of its research fronts that to remain on the leading edge, the Laboratory must engage researchers at many academic centers of excellence. In the last two years, the ISCR has dramatically expanded the Laboratory's bridge to the academic community in the form of Laboratory Directed Research and Development (LDRD) efforts involving university

A Laboratory-led team (right), collaborating with the University of Minnesota and IBM, solved a supercomputer problem with broad applications and was awarded the 1999 Gordon Bell Award for best performance at the Supercomputing '99 Conference. A second "special prize" was awarded to a team including LLNL, Old Dominion University, NASA and Argonne National Laboratory. At left, Gordon Bell and ISCR Acting Director David Keyes, co-recipient of the "special prize".

collaborators, University Collaborative Research Programs (UCRP), visiting faculty, student internships, a workshop, and a very active seminar series.

ISCR research participants are seamlessly integrated with the Laboratory's Center for Applied Scientific Computing (CASC), which, in turn, addresses computational challenges arising throughout the Laboratory. Administratively, the ISCR flourishes under the Laboratory's University Relations Program (URP). Together with the other four Institutes of the URP, it must navigate a course for the Laboratory to benefit from academic exchanges while preserving national security.

Relying primarily on non-permanent staffing, the ISCR complements Laboratory research in areas of the computer and information sciences that are needed at the frontier of Laboratory missions. The ISCR works with CASC in being the "eyes and ears" of the Laboratory in the computer and information sciences, that is, in keeping the Laboratory aware of and connected to important advances occurring externally. It also attempts to be "feet and hands" for the Laboratory by carrying those advances into LLNL and incorporating them into practice.

The ISCR has begun to and will increasingly provide continuing education opportunities to Laboratory personnel in the form of on-site workshops taught by outside experts on new software or hardware technologies.

The ISCR also seeks to influence the research community external to the Laboratory in order to pursue Laboratory-related interests and to train the workforce that will be required by LLNL and DOE. Part of the performance of this function is interpreting to the external community appropriate (unclassified) aspects of the Laboratory's own contributions to computer and information sciences — contributions that its mission and resources give it a unique opportunity and responsibility to make.

Of the three principal means of packaging scientific ideas for transfer — people, papers, and software — experience suggests that the most effective means is people. The programs of the ISCR are therefore people-intensive.

In 1998, the ISCR hosted 148 visitors, who gave a total of 53 seminars on site. Twenty-three students participated in residence. In 1999, the ISCR hosted 167 visitors, who gave a total of 80 seminars on site. Thirty-nine students participated in residence. The vast majority of the visitors were from academia, with about 14% from industry and about 8% from other laboratories. In both 1998 and 1999, the ISCR sponsored eight graduate students on University of California campuses through the University Collaborative Research Program (UCRP).

ISCR Research Highlights

Novel Parallel Numerical Methods for Radiation and Neutron Transport

The availability of advanced computational methods for transport modeling is of crucial importance to the Department of Energy. In many of the multi-physics simulations performed at the Laboratory, transport calculations can comprise from 30-50% of the total run time. This project, done in collaboration with University of Colorado at Boulder and the University of Washington, enhanced capabilities for simulating the transport of radiation and neutrons through the design of advanced numerical methods for parallel computers. The equations describing transport processes are usually variants of the Boltzmann transport equation, which requires the solution of very large systems of equations. The ability to solve such problems efficiently requires a combination of several kinds of numerical methods on parallel computers.

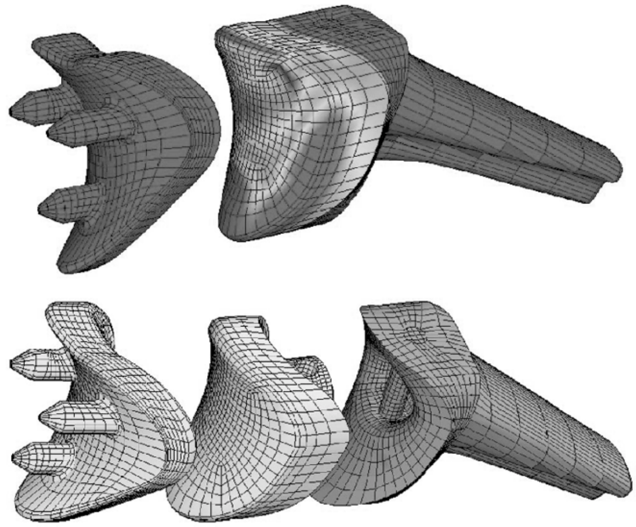
Developments in the new area of first-order system least squares (FOSLS) methods show great potential for providing more accurate and robust solution procedures than current approaches. The FOSLS-based approach also provides a natural solution procedure using efficient multigrid techniques. The algorithmic advances explored in this LDRD project are now being incorporated into the Laboratory's radiation transport analysis codes.

A New Approach to Orthopaedic Implant Design

Orthopedic implants currently have shorter service expectancies than the life expectancies of their recipients. Most implants fail after at most 15 years, and 39 percent of implants go to patients who are less than 65 years old. The trauma of replacement implants is significantly worse than that of the original, which puts a premium on the design of longer-lived custom implants. This project, conducted jointly with the Mechanical Engineering Department at the Laboratory, UC Berkeley, UC Davis, UC Irvine, UC San Francisco and the University of New Mexico, developed a computational method to evaluate designs for orthopaedic implants before they are manufactured or surgically implanted. ISCR's approach to implant design uses finite element computer modeling (FEM) of joints with implants to simulate their mechanics, that

"My summer stay at LLNL was a productive visit, spent at an excellent work environment with nice people to work with. The experience that I gained and the things that I learned here will be very useful in my future work at the Laboratory."

Ana Iontcheva, 1999 Summer Intern, UC Davis



A new prosthetic implant design for the thumb joint. ISCR models the behavior of each design with physiological loads applied. This technique uniquely reveals regions of high stress verses relatively low stress.

is, their motion and deformation in response to applied forces characteristic of human activities.

This is an attractive alternative to current methods used to design implants that use only experimental testing for design evaluation. Failures of implants depend on implant and human tissue geometry, the constitutive properties of the biological and the implant materials, and/or interaction between the human tissues and the implant components. The ISCR demonstrated that computational modeling can contribute to early changes in the design process, resulting in better, less costly implants, which should last longer in the body.

SAVAnTS: Scalable Algorithms for Visualization and Analysis of Terascale Science

Computational simulation data are collected in too large a volume to be assimilated apart from synthetic visualization and at a far greater rate than they can be visualized in raw form on the fly. SAVaNTS attacks both of these problems, adding to the interpretability of data while compacting its storage requirements. This project between CASC, U.C. Davis, University of Texas, Austin, and LLNL Defense and Nuclear Technology scientists is developing and applying efficient multi-resolution and compression methods for high-performance visual exploration and precise quantitative analysis of extremely large scientific data volumes (terabytes to petabytes). These methods permit computational scientists to sample output data at many different resolutions. Coarse resolutions are useful for fast network transfers, fast real-time visualization and interaction, and low storage. Fine resolutions may be necessary for drawing accurate conclusions from the data. Adaptive multi-resolutions, the product of this research, provide the best of both extremes – reasonably compact data sets that can be explored with accuracy where the accuracy is required, as determined by automated means or by the investigator. Multi-resolution is complicated for data

ASCI Pacific Blue Computer System at LLNL.

on time-dependent, unstructured, adaptive three-dimensional grids in general geometries, and multi-resolution algorithms are nontrivial to parallelize efficiently.

The algorithms being developed for this difficult problem class characteristic of ASCI will be fully scalable and efficiently implemented on distributed- or shared-memory parallel systems. Initially, they are being applied to ASCI and Defense Nuclear Technologies physics simulations; a broad range of further applications will be aggressively pursued.

Sapphire: Scalable Pattern Recognition for Large-Scale Scientific Data Mining

Many features that scientists wish to find in data cannot be defined precisely in terms of pointwise values, but only in complex relationships between data. The human visual cortex is unrivaled in its ability to discover interesting features in scientific visualizations, but it is easily overwhelmed and is error-prone. This LDRD project between CASC, UC Davis, UC Irvine, the Institute for Geophysics and Planetary Physics (IGPP), and LLNL Defense and Nuclear Technology scientists is developing scalable data mining algorithms for the interactive exploration of large, complex, multi-dimensional data sets. For example, this work helps astrophysicists look for galaxies of interest using objective, semi-automated techniques instead of a subjective, manual approach. The problems facing astrophysicists as they explore terabyte data sets will worsen as the ASCI simulations produce petabyte data sets.

Sapphire uses techniques from data mining, which is the semi-automated discovery of patterns, associations, anomalies, and statistically significant structures in data. It consists of two steps – in data pre-processing, it extracts high level features from raw data, and in pattern recognition, it uses these features to discover and characterize patterns in the data. The focus of this project is on image processing algorithms for extracting features from image data, and decision trees and neural network techniques for pattern recognition. The objective is to design and develop parallel algorithms and software that are scalable, robust, accurate, and interpretable. Sapphire is being developed on two test-bed problems – identification of galaxies with a bent-double morphology and identification of asteroids in large astrophysical databases. ISCR's decision tree technique recently found a bent-double galaxy that was overlooked during a manual search of part of the data, revealing the potential of data mining techniques.

The Future

The ISCR's influence will be significantly augmented for FY2000 and beyond due to the presence of a new sister organization at LLNL, the ASCI Institute for Terascale Simulation (ITS). The ITS includes a major university collaborations component of Livermore's ASCI program, and will bring to the Laboratory workshops, a short course, additional sabbatical visitors, and a series of survey talks by distinguished lecturers in computational science. In addition, the Internships in Terascale Simulation Technology (ITST) summer program will substantially increase the number of graduate students in residence at the Laboratory doing collaborative research that will prepare them for roles in the future of stockpile stewardship and other critical DOE computational technologies. The ISCR provides natural and effective administrative coordination for these new programs.

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FY98–99

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ISCR University Collaborative Research Projects (UCRP) in FY 1998-99

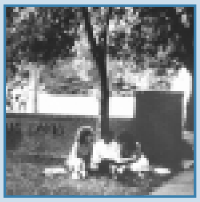
During FY 1998-99, ISCR and CASC facilitated collaborations between LLNL staff and colleagues at five of the nine University of California campuses, on a total of twelve research projects.

UC Berkeley

"A Computational Investigation of Finite-Strain Plasticity Models for Crystalline Solids"
Panayiotis Papadopoulos, UC Berkeley; Daniel J. Nikkel Jr., LLNL, Mechanical Engineering

"Massively Parallel Computation Applied to Finite Element Analysis"
Tony Keaveny, UC Berkeley; Karin Hollerbach, LLNL, CASC

UC Davis



"Parallel Multigrid Methods on Unstructured Grids for Scientific Computing"
Tony Chan, UC Los Angeles; Robert Falgout, LLNL, CASC

"Parallel Particle-in-Cell Modeling of Semiclassical Quantum Models"
Viktor Decyk, John M. Dawson, UC Los Angeles; Dennis Hewett, LLNL, CASC

"Development of a Three-Dimensional Relativistic Particle-In-Cell Code for Studying the Production of Useful Electron Bunches Using Ultra-Intense Laser Pulses"
Warren B. Mori, UC Los Angeles; Scott Wilks, LLNL, X-Division

"Global Simulation of the Earth's Magnetosphere with Adaptive Mesh Refinement"
Joachim Raeder, UC Los Angeles; Scott Kohn, Richard Hornung, F. Xabier Garaizar, LLNL, CASC

"High-Resolution Parallelized Self-Organizing Maps for Visualizing Patterns of Human Cortical Activation"
Jackson Beatty, UC Los Angeles; Farid Dowla, LLNL, Electronics Eng. - EETD

UC Los Angeles

"Computational Fluid Dynamic Studies of Arterial Flow Disturbances Induced by Intravascular Stents"
Abdul Barakat, UC Davis; Patrick Fitch, LLNL, BBRP

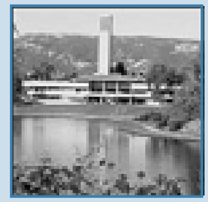
"High Frequency Seismic Wave Field Computation on a 3D Heterogeneous Earth Model by Means of Coupled Normal Mode Synthesis"
Fred Pollitz, UC Davis; Dennis Matthews, LLNL, Medical Technology Program

UC San Diego

"Software Infrastructure for Multi-Tier Implementation of Structured Adaptive Mesh Hierarchies"
Scott Baden, UC San Diego; John May, LLNL, CASC

"Methods of Simulation for Localized Multiply-Scaled Condensed Materials"
John Weare, UC San Diego; Scott Kohn, LLNL, CASC

UC Santa Barbara



"Algorithms and Software for Sensitivity Analysis of Large-Scale Differential-Algebraic Systems"
Linda Petzold, UC Santa Barbara; Peter Brown, LLNL, CASC

Materials Research Institute

The mission of the Materials Research Institute (MRI) is to collaborate with the best university researchers to enhance LLNL programs in areas of cutting-edge materials science.

The Materials Research Institute (MRI), the newest of the University/LLNL Institutes, began operation in March 1997. The MRI is focusing on three primary areas of materials research: Electro/Optical Materials, Biomaterials, and Metals/Organics. In this section are highlighted several projects within each area that have made significant advances.

A fundamental goal of the MRI is to foster discussion and interaction between LLNL and university researchers, and among LLNL researchers from different Directorates. This is accomplished through a weekly seminar series, special seminars such as Biomaterials and Applications of High Pressure Science, conferences and workshops, an extensive visitors program, and MRI lunches.

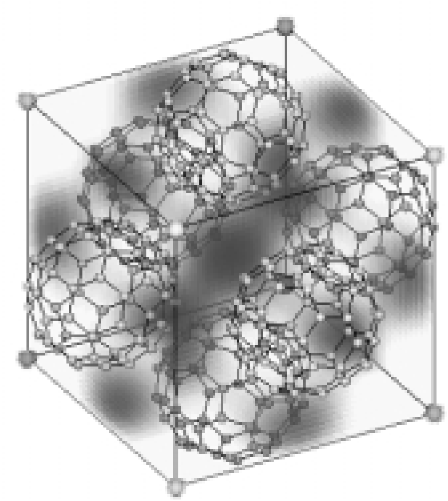
One of the main objectives of the MRI is to use its portfolio to help develop the next generation of materials scientists for LLNL and DOE. The Institute is especially pleased to have housed five graduate students who are performing their thesis research in residence at the MRI, and to have supported seventeen additional graduate students who are performing their thesis work on campus in collaboration with an LLNL researcher. As the Institute continues to grow, MRI looks forward to expanding and strengthening the variety of collaborations, which form the basis of its research activities.

Metals/Organics

New Theoretical Framework for Computing Positron Annihilation Characteristics

Positrons, the antiparticles of electrons, are elementary particles with the same mass as electrons but positive electric charge. Positrons annihilate with electrons, producing two or more gamma rays. When positrons are injected into materials, they seek out open volume regions away from the atomic positions as a result of their repulsive interaction with the similarly charged atomic nuclei. This property makes positrons very sensitive to defects in materials, such as vacancies, missing atoms in the crystal lattice, and vacancy clusters. By measuring the gamma rays emitted when the electron and positron annihilate, researchers can identify a variety of defects and their concentrations in the material, and determine the atomic species associated with these defects.

Theoretical calculations of positron observables are essential for interpreting positron experimental data. In collaboration with UC Davis, a new computer program using the general Finite-Element (FE) approach for calculating positron lifetimes and distributions in materials was developed. In contrast to previous tools, this versatile method is suitable for calculations on very large systems and for both open



Positron distribution in crystalline fullerene carbon-60. For clarity, the carbon-60 molecules on the cube edges have been replaced by single atoms.

My work at LLNL "helped me to understand the importance of my inorganic synthetic chemistry training and to apply the properties of a new material to push technology forward . . . Seminars sponsored by MRI helped me to understand the collaborative nature of current research, and (allowed me to get acquainted) with many excellent scientists . . ."

Boyd Taylor, Graduate Student UC Davis

and close-packed atomic geometries. It is now an established tool for calculating positron lifetime in the Positron Group at LLNL.

The reliability of this program was tested by calculating the positron lifetimes for 23 elemental metals and a number of elemental metal vacancies in metals, and excellent agreement both with previous calculations and experimental data was obtained. A three-dimensional (3D) representation of the positron distribution in the crystal structure of the fullerene molecule carbon-60 is shown on page 33. This calculation on an openly packed crystal structure was performed on a fairly large 240-atom unit cell. The positron avoids the centers of the soccer-ball-shaped carbon-60 molecules and occupies the space in the lattice between the fullerenes, as far away from the atoms as possible.

Extreme States of Matter on Nova

One technique to measure the lattice structure of a material is by x-ray diffraction. The pattern of diffracted x-rays provides detailed information about the crystalline lattice planes. This technique has been applied with time resolution to study the lattice structure of a material as it is deformed by high-pressure shock compression. LLNL researchers collaborated with colleagues from UC San Diego, University of Oxford, and Los Alamos National Laboratory to successfully develop this technique of dynamic x-ray diffraction on intense lasers. Demonstrated dynamic diffraction measurements of (111) and (400) Silicon (Si) lattices that were shock compressed with the Nova laser at LLNL and on the Trident laser at Los Alamos have been demonstrated.

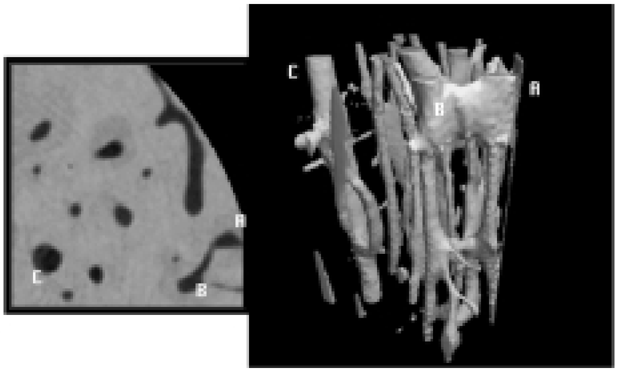
The goal of this project was to technically assess whether the technique of dynamic diffraction could be developed into a robust diagnostic of solid-state lattices under shock loading. MRI researchers recorded x-ray diffraction signals from thin single crystals of Si as a shock wave launched by the laser drive traveled through the crystal. These diffraction signals were recorded using an x-ray streak camera with nanosecond time resolution. Observations were successfully made of the compression of the Si lattice along the shock propagation direction. LLNL will continue to develop the ability to measure compression of the lattice in multiple orthogonal directions in order to characterize elastic vs. plastic (3-D) compression of the crystal due to the shock. This work is continuing on the Omega and Trident lasers at Rochester and Los Alamos, respectively.

Elastic Constants of Ta at High Pressures and Temperatures Determined by Stress- and Angle-Resolved Synchrotron X-Ray Diffraction in a Diamond-Anvil Cell

Elastic moduli provide information about macroscopic behavior, the bulk and shear modulus, and are required for a complete understanding of the thermoelastic properties of materials. Especially in geophysical applications, information of the elastic properties is essential for determining accurate equations of state and for computing the compressional and shear-wave velocities. Such information is fundamental to our understanding of the composition, structure, thermal properties, and evolution of the Earth.

LLNL investigators along with collaborators from UC Los Angeles have developed a new experimental technique—Stress and Angle-resolved X-ray diffraction (SAX). Using this technique, the lattice strain of Ta was measured to over 1 Mbar. The elastic constants C_{11}, C_{12}, and C_{44} for the bcc Ta were estimated as a function of pressure. The results indicate qualitative agreements with theory and the existing strength model.

The group also measured isothermal compressibility of Ta near to 2 Mbar. The accurately confined pressure derivative based on these measurements of the compressibility of Ta places allows the equation of state of Ta to be the most precise pressure standard in diamond-anvil cell research. This is an important achievement



Bone structure on a microscale: Sites of remodeling in the active mineralization phase in the osteon (tomographic cross-section on the left). The three-dimensional surface of the void spaces (at a constant mineral content) shows the canal networks orientation and fine details of the surfaces. Locations A, B, and C in the tomographic cross-section are mapped onto the tissue surface.

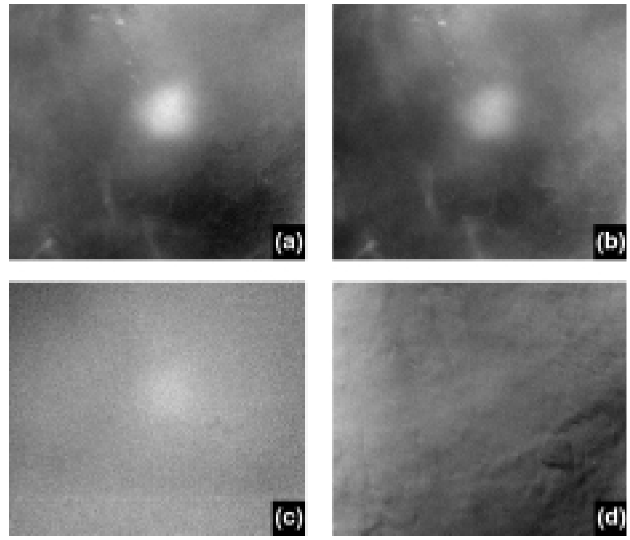
applicable to materials research worldwide.

Biomaterials

Micromechanical Modeling of Cortical Bone Deformation

Cortical bone is an extremely variable biological composite material system capable of adaptive structural changes in response to the types and quantities of loading experienced. The elastic stiffness and fatigue strength of cortical bone have been shown to vary with anatomic site, age, strain rate, and loading direction. The fatigue of bone under normal physiological loading conditions increases with age and could cause microdamage accumulation. Understanding the deformation models of cortical bone requires knowing precise tissue level properties and microstructural detail.

To study the three-dimensional nature of microstructure and the locations where bone damage is initiated, researchers utilized four experimental techniques: x-ray tomographic microscopy (XTM), atomic force microscopy, electron microscopy, and mechanical deformation to generate data as model input parameters. In collaboration with UC San Francisco, the MRI Team was able to identify the mineralization state associated with the bone remodeling process, architectural length scales, and variations in mineralization with age from the XTM data.



Subsurface images of a high scattering object located 1-cm underneath the surface of chicken breast tissue using the spectral polarization difference imaging technique and 600 nm, 690 nm, 770 nm and 970 nm illumination. (a) [970-600] nm SPDI image, (b) [970-770] nm SPDI image, (c) [770-690] nm SPDI image and (d) [690-600] nm SPDI image.

The approach, to be explored further in the future, is incorporation of the tomographic data into finite-element models. Success in these efforts could advance the basic science underlying the diagnosis and treatment of osteoporosis.

Center for Laser Imaging and Cancer Diagnostics

The objective of this research effort is to develop a subsurface imaging system that can offer enhanced imaging depth (up to 1 cm) based on the spectral polarization difference imaging technique (SPDI). SPDI is an optical technique that reveals the image information of an object located deep beneath the surface. Such a system could significantly enhance technology for cancer screening. This technique requires the use of different illuminating wavelengths in combination with polarization techniques to obtain images of subsurface tissue structures at different depth zones based on their difference in absorption, scattering and depolarization. This project is part of a DOE Center for Excellence in Laser Medicine, which is based at

City College of New York (CCNY), and is hosted at LLNL within the MRI.

In the future, this technology will be applied to an imaging system being built for use in the pathology room at the UC Davis Cancer Center. This system will be computer controlled and user friendly. The aim is to investigate the usefulness of the technology in a clinically relevant environment.

Determining the Structure of Biomaterials Interfaces Using Synchrotron-based X-ray Diffraction

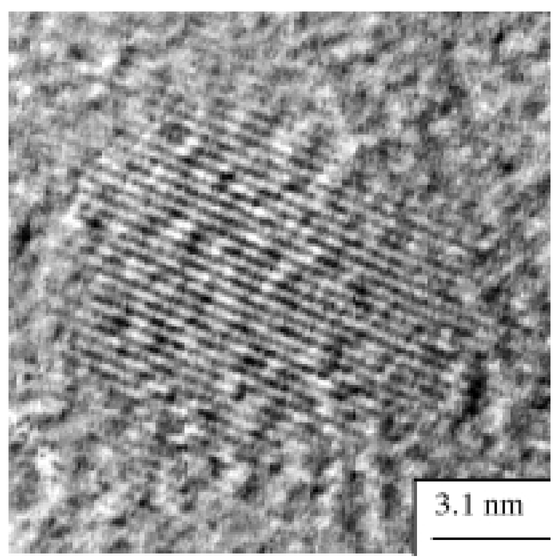
Many organisms exhibit control over biomineralization processes, resulting in exquisitely tailored crystalline architectures. Control may involve the introduction of proteins that interact with growing crystals, the carefully timed introduction of ions, the removal of trace elements, and so on. These processes occur at crystal surfaces; specifically, they are processes mediated by atoms at the solid/solution interface. Understanding such processes requires tools for probing surfaces and near-surface atomic structure in fluids. Surface x-ray diffraction (SXRD) provides crystal structure at the atomic level, surface molecular structure, the stereochemistry of adsorbates, and the stereospecificity of binding sites. This method provides a crucial link between experimental surface techniques, such as scanned probe microscopy, and theoretical tools like kinetic Monte Carlo and molecular dynamics, all of which are playing increasing roles in detection, identification and characterization of biological molecules and materials. The goal of this project is to build a competency for LLNL in x-ray analysis of fluid/solid interfaces by using third generation syncrotron sources to determine the interface structure of biomaterials, applying it to simple model biomineral systems, and comparing the measured interface structure with predicted structures based on crystallographic modeling.

MRI researchers have chosen the systems calcium carbonate and calcium phosphate in aspartic and glutamic acid-bearing solutions as models. The calcium compounds are ubiquitous among biomineral structures, while the two acidic amino acids - both as simple and polyamino acids - are the dominant constituents of protein molecules implicated in the control of biomineralization. MRI collaborators on this project included Argonne National Laboratory, UC Santa Barbara, the University of South Alabama and the University of Nijmegen, Netherlands.

Electro/Optical Materials

The Study of Photoluminescence and Device Applications of Si Quantum Dots

Quantum dots (QDs) are particles a few nanometers in size and typically contain less than a thousand atoms. At these sizes, three-dimensional quantum confinement (QC) of electrons and holes gives rise to optical and electrical properties that are highly size and shape dependent and dramatically altered from their bulk counterparts. Thus QC in QDs provides a convenient and versatile method to tailor or generate new material properties. In collaboration with UC Davis, LLNL pioneered a solution synthesis technique to prepare Si and Ge QDs with either oxide or organic groups attached to the QD surface. The figure below represents a High-Resolution Transmission Electron Microscopy (HRTEM) micrograph of methyl-terminated Si QDs. Lattice fringes consistent with the {111} crystal plane of Si are observed. For some of the larger QDs (≥5nm), the facets of a hexagonal shape can be discerned. Our synthesis typically produces sizes that range from 1 nm to 5 nm. These QDs display a variety of size-dependent optical and electronic properties. The light emission from these QDs can be tuned from the red to the ultraviolet by simply changing the QD size. This enables a new generation of optoelectronic and photonic devices, leading the LLNL/UC Davis team to fabricate blue light emitting diodes with these QDs.



An HRTEM image showing lattice fringes of an Si nanocluster.

Nanoscale Study of Strain and Strain Dynamics in Nonlinear Optical Materials

Strain and fracture dynamics is an exciting new area of physics. In collaboration with UC Riverside, MRI is studying surface stress and strain dynamics in topical components (laser materials and nonlinear optical materials) with nanometer resolution using a variety of scanning microscopes such as the Near-Field Scanning Optical Microscope (NSOM), the Atomic Force Microscope (AFM) and the Scanning Tunneling Microscope (STM). The stresses in optical components are associated with defects incorporated during fabrication of the optical components, especially the cutting and polishing stages. These nanoscale stresses and strains will exacerbate mechanical failure mechanisms in the optical components. Also, given the high intensity optical beams that are transmitted through the optical components, even a small phase difference and/or polarization rotations that are introduced by the nanometer scale defects could eventually result in a loss of coherence in the transmitted optical beam. MRI researchers have used NSOM and AFM to identify and characterize nanometer-sized surface and sub-surface defects in optical components at LLNL.

The Future

Over the past several decades, a large part of materials science research has been focused on reducing the dimensions of devices. Important, powerful tools, like the growing range of scanning probe microscopy methods, are being applied to learn about materials properties on the submicron scale and down to the single molecule level. Multiscale computational methods are moving to bridge from the atomic level across the nanoscale regime. The attention on nanoscience and technology was highlighted early in 2000 when President Clinton announced the White House's initiative, "Nanotechnology for the Twenty-first Century." Since nanoscience really is the science of materials, it will continue to become more of a focus for the MRI, especially in those areas that can help support LLNL and U.S. DOE programs.

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William Nellis
Ken Turtletaub
Wayne King
John Klepeis
Rich Howell
Tony Gonis

Post Docs
Rezik Agbaria
Mary McBride

Students
FY98–99: 63

Faculty
FY98–99: 5

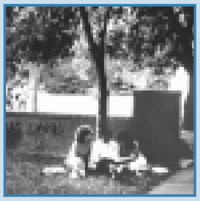
MRI University Collaborative Research Projects (UCRP) in FY 1998-99

UC Berkeley

"Optically-Induced Structural Changes in Materials"
Roger Falcone, UC Berkeley; Troy Barbee, LLNL, Physics

"High Pressure Synthesis and Characterization of Carbon Nitrides"
Ray Jeanloz, UC Berkeley; Jeff Nguyen, LLNL, Physics

UC Davis



"New Theoretical Framework for Computing Positron Annihilation Characteristics"
Philip Sterne, UC Davis; Richard Howell, LLNL, Physics

"Device Miniaturization Through Self-Assembly: An In-Situ AFM Study of Molecular Scaffolds"
G. Taynas Palmore, UC Davis; James De Yoreo, LLNL, Chemistry and Materials Sciences

"The Study of Photoluminescence and Device Applications of Si Quantum Dots"
Susan Kauzlarich, UC Davis; Howard Lee, LLNL, Physics

UC Los Angeles

"Dislocation Dynamics Simulation of Radiation Hardening"
Nasr Ghoniem, UC Los Angeles; Tomas Diaz De La Rubia, LLNL, Chemistry and Materials Sciences

"Rapid Synthesis of Materials at High Pressures"
Richard Kaner, UC Los Angeles; Hector Lorenzana, LLNL, Physics

"Measuring the Thermal-Mechanical Properties of Multi-Layered Thin Films"
Greg Carman, UC Los Angeles; Troy Barbee, III, LLNL, Physics

UC Riverside

"Study of the Role of Coherent Phonons and Shock Waves on Energy Transfer Processes During Femto Second Laser-Induced Melting of Solids"
Harry Tom, UC Riverside; Choong-shik Yoo, LLNL, Physics

"Nanoscale Study of Strain and Strain Dynamics in Laser Materials and Nonlinear Optical Materials"
Umar Mohideen, UC Riverside; Ming Yan, LLNL, Chemistry and Materials Sciences

UC San Diego

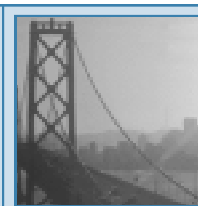
"Synthesis and Properties Modification of Novel f-electron Materials by Shock Compaction"
M. Brian Maple, UC San Diego; William Nellis, LLNL, Physics

"Thermodynamic Measurements of High-Energy-Density Storage Materials"
Frances Hellman, UC San Diego; Hector Lorenzana, LLNL, Physics

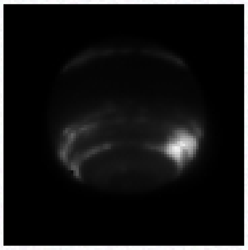
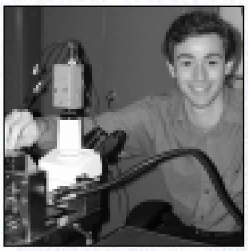
"Magnetic Circular Dichrosim in Half Metallic Magnets"
Ian Schuller, UC San Diego; Jim Tobin, LLNL, Chemistry and Materials Sciences

"Experimental Correlations of Deformation Strain Gradients and Grain Boundary Character Distribution (GBCD)"
Bimal Kad, UC San Diego; Adam Schwartz, LLNL, Chemistry and Materials Sciences

UC San Francisco



"Micromechanical Modeling of Cortical Bone Deformation"
Thomas Breunig, UC San Francisco; John Kinney, LLNL, Chemistry and Materials Sciences

Programs

URP serves as the Laboratory focal point for extensive university collaborations and has direct line management responsibility for several LLNL programs involving collaborative research, education and the development of future Laboratory employees

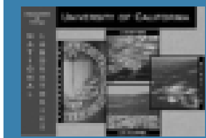
UC Directed Research and Development

Lawrence Livermore Postdoctoral Fellowship Program

Research Collaborations Program for Historically Black Colleges and Universities and Minority Institutions

National Physical Science Consortium

Science and Technology Education Program



UC Directed Research and Development

One function of the University Relations Program (URP) is to serve as the Point-of-Contact with the UC Office of the President for Lawrence Livermore National Laboratory in the area of collaborative research.

The University of California (UC) is a state institution which manages three national laboratories for the U. S. Department of Energy under a five-year contract. Under the umbrella of this contract, LLNL participates in a number of programs initiated by the UC Office of the President (UCOP), most of which have a collaborative research element for which the University Relations Program (URP) performs a management function for the Laboratory. In this section a few representative examples of work funded from UC Directed Research and Development (UCDRD) funds are highlighted.

UCDRD Projects

According to the contract between DOE and UC, a portion of the management fee may be used for "UC Directed Research and Development" at the laboratories. In 1994, the management of these funds became part of the University Relations Program's function.

Research Projects

The URP focuses some UCDRD Funds on "window-of-opportunity" research projects. All but the smallest of these projects are peer reviewed by experts in the field.

Adaptive Optics

DOE's high-powered lasers at LLNL are benefitting from a new technology called adaptive optics, which is used to improve laser beam quality. Now LLNL researchers are applying this expertise to improve images on the world's largest optical telescope.

The Earth's turbulent atmosphere has always limited astronomers' ability to see sharply. That is one reason NASA spent about $1.5B to put the Hubble Space Telescope into orbit. With support from the UCDRD program, a team lead by LLNL scientists and including collaborators from UC Berkeley, UC Los Angeles, and the Keck Observatory in Hawaii developed a solution to this age-old problem.

Adaptive optics technology uses rapid mirror adjustments to remove the effects of Earth's atmospheric turbulence from the telescope's images, thereby producing unprecedented clarity. The system is installed on the W. M. Keck II telescope, the world's largest, and has been used to produce dramatic new images of Neptune and Saturn's largest moon, Titan.

Adaptive optics imaging works by using a continuously deformable mirror and a lightwave sensor to correct light beaming into a telescope. The sensor determines how the Earth's atmosphere is disturbing the light reaching the telescope, and subsequently relays this information to

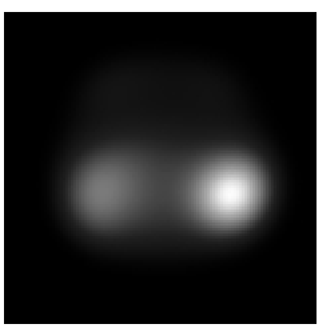


Image of Neptune without adaptive optics.

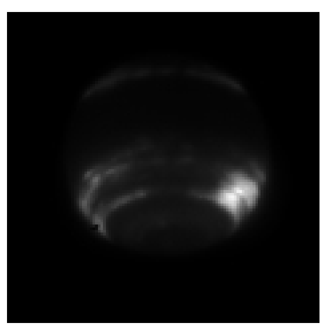


Image of Neptune taken with the Keck II Telescope adaptive optics system in infra-red light, wavelength 1.65 microns, on May 24, 1999.

the deformable mirror, which corrects the image every few milliseconds.

The adaptive optics infrared images reveal giant infra-red-bright "storms" on Neptune driven by prevailing winds of 600 miles per hour. On Titan they reveal what appear to be frozen land masses separated by chill hydrocarbon seas and lakes. The level of resolution in the images surpasses even that achievable using the Hubble Space Telescope at the same wavelengths.

In the near future, a new spectrograph will be added to the Keck adaptive optics system. This equipment will help answer more questions about the chemical composition and physical state of the features observed on Neptune and Titan. The Cassini spacecraft, built by NASA and the European Space Agency, is scheduled to land the Huygens probe on Titan in 2004. Keck's new images will help researchers determine beforehand whether the probe will plunge into an extra-terrestrial sea or land on a solid surface.

Use of Self-Induced Plasmas to Focus High-Energy Electron Beams

A major issue in the use of accelerators for colliding beam experiments in the study of high-energy physics is the control and focusing of beams in order to increase the chances of collision between particles. UCDRD support allowed the participation of researchers in LLNL's Institute for Laser Science and Applications (ILSA) in a major project involving collaboration between the Stanford Linear Accelerator Center (SLAC), Lawrence Berkeley National Laboratory, UC Los Angeles, University of Southern California, Fermi National Accelerator Laboratory, University of Rochester, Hiroshima University (Japan) and the University of Tennessee. The project has focused on the use of self-induced plasmas to focus high-energy electron beams.

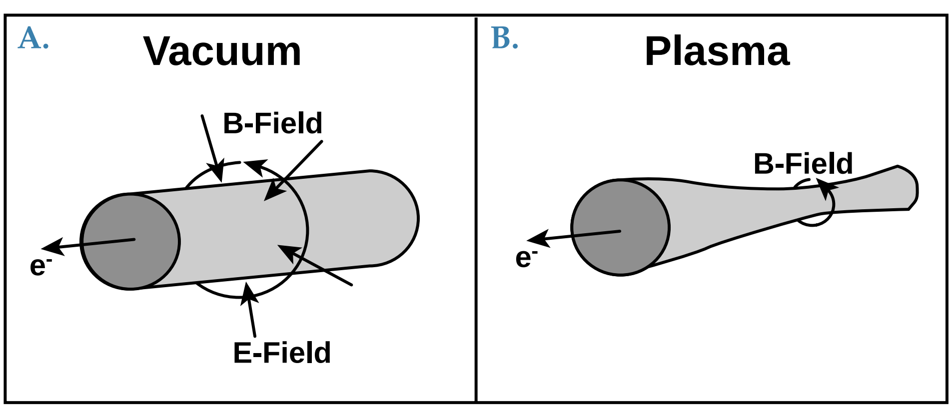
Important results have been achieved through this multi-institution effort. The experiment was carried out at the SLAC Final Focus Test Beam, with nominal parameters of 30 GeV beam energy. Researchers observed a reduction of 40% in the size of the beam dimension for plasma lengths of 3mm when the beam is passed through gaseous plasma. This reduction in focal length indicated a focusing strength approximately 100 times that of the final focus magnets. The synchrotron radiation with critical energy in the 1-10 MeV range due to the strong bending of beam particles inside the plasma lens was also observed for the first time.

University Collaborative Research Program (UCRP)

UCDRD Funds also support the University Collaborative Research Program (UCRP) at LLNL's Institutes. An annual UCRP "Call for Proposals" is issued from each of the five Institutes reporting to URP. The UCRP is a competitive, peer-reviewed process supporting small research projects that benefit Laboratory programs. Projects usually involve one graduate student working on his or her Ph.D. thesis, a postdoctoral fellow, or a researcher with relevant expertise. The University researcher must collaborate with an LLNL scientist. The LLNL scientist serves either as a thesis mentor for the student, or works on the project, contributing a unique expertise to the research.

Sensitivity and Uncertainty Analysis for Large-Scale Differential Algebraic Systems

Computer simulations are used widely in the investigation of complex physical problems. The general behavior of physical systems can often be mod-



In a vacuum, the electric force is balanced by the self-induced magnetic field (A). In a plasma, the presence of the positively charged ions reduces the electric force and the B-field pinches and focuses the beam (B).

eled as a set of ordinary differential equations (ODEs), along with certain parameters, initial values and boundary conditions that describe specific problem features. LLNL's Institute for Scientific Computing Research (ISCR) and the Center for Applied Scientific Computing (CASC) are collaborating with UC Santa Barbara (UCSB) on a UCRP initiative to develop mathematical software for analyzing the sensitivity of computer-modeled simulations with respect to the parameters contained in the model.

Conceptually, the simplest approach to sensitivity analysis is to perform numerous simulations in which only one parameter is varied at a time. The LLNL-UCSB research project, however, is pursuing a more systematic and practical approach of solving the so-called sensitivity differential equations together with the ODEs that describe the simulation. Such sensitivity information is useful because it allows the scientist to identify which parameters are most influential in affecting simulation results. This information is also valuable for sensitivity applications such as model simplification or design optimization. Results of this effort are being incorporated into a heavily used parallel computer code, developed and maintained at CASC, to outfit the code for efficient generation of sensitivity data.

Advanced X-ray Diagnostics

X-ray diagnostics depend heavily upon the use of crystals in virtually all applications. Therefore, the study of the basic physics of crystals under stress holds the promise of improving diagnostic techniques for laser science. Recent developments in time-resolved x-ray diffraction, using both synchrotron and laser plasma-based sources, have led to the capability of directly observing structural phase transitions, the motion of complex molecules, and chemical reactions on pico-second-time scales. This has resulted in a number of novel experiments, including the investigation of short-pulse-laser irradiation of organic films and ultra-fast laser-induced phase transitions in semiconductors.

Researchers in LLNL's Institute for Laser Science and Applications (ILSA), teamed with the Physics Department at UC Berkeley, have investigated x-ray diffraction from laser-induced structural changes in materials. Time-resolved x-ray scattering has been used to characterize rapidly evolving crystal structures. Ultra-fast detector technology was developed on the Advanced Light Source synchrotron beam line at the Stanford Linear Accelerator Center (SLAC), allowing the team to study melting of ultra-short-pulsed-laser-illuminated materials and measure coherent phonons and bond breaking. The entire time history of the diffracted signal following laser excitation was measured at once, in contrast to more typical pump-probe geometries. This work has shown that time-resolved x-ray diffraction is a useful tool in phonon spectroscopy and a sensitive probe of electron-phonon coupling strengths.

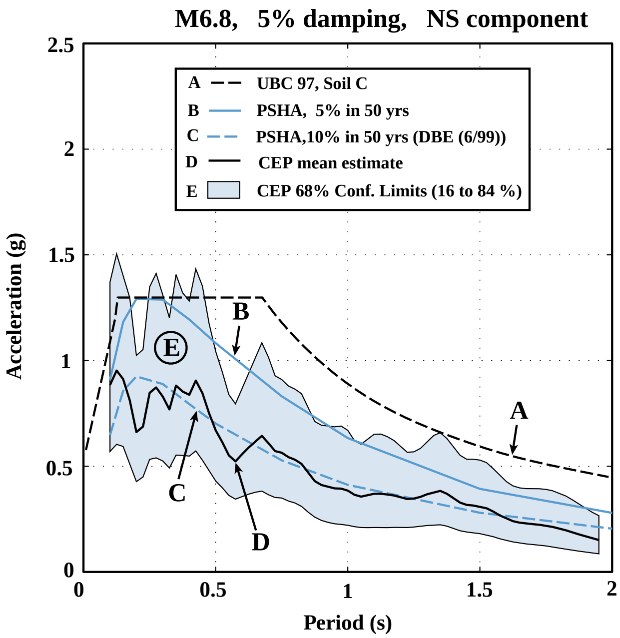
The Campus Laboratory Collaborations (CLC) Program

In 1995, the UC Office of the President initiated the Campus Laboratory Collaborations (CLC) program. This program funds three-year research projects involving collaboration from many disciplines and institutions to solve complex problems. Competition for CLC projects was opened to every Principle Investigator (PI) from the nine UC campuses and the three UC-managed national laboratories. The UCOP selected significant problems for investigation in the first phase of the program; problems which were also germane to the welfare of California. The topics selected were: understanding earthquakes and researching possible hazard mitigation techniques, water resource management, materials research, and Pacific Rim growth. The LLNL portion of the research expenses is supported by UCDRD funds, while campus researchers are supported by UC's CLC funds.

The second phase of the CLC started in July 1998 with five projects selected involving LLNL.

Estimation of the Ground Motion Exposure from Large Earthquakes at Three UC Campuses in Southern California

The UC/CLC Campus Earthquake Program (CEP) started in March 1996, and has involved a partnership between seven campuses of the University of California—Berkeley, Davis, Los Angeles, Riverside, San Diego, Santa Barbara, Santa Cruz—and the Lawrence Livermore National Laboratory. The aim of the CEP is to provide University campuses with site-specific assessments of their strong earthquake motion exposure, in addition to estimates they obtain from consultants according to the state-of-the-practice, i.e., Building Codes, and Probabilistic Seismic Hazard Analysis (PSHA). The Building Codes are highly simplified tools, while the more sophisticated PSHA is still somewhat generic in its approach because it usually draws from many earthquakes not necessarily related to the faults threatening the site under study. Each campus has selected a critical site to demonstrate the methods and procedures



Surface strong motion estimates for the U.C. Santa Barbara Engineering I building. The estimates are for the UBC 97 building code (line A), the Probabilistic Seismic Hazard Analyses (PSHA) with different earthquake return periods (lines B and C), and the Campus Earthquake Program (CEP). The mean of the CEP results is line D and the range of + -1 standard deviation is area E. The current Design Basis Earthquake (DBE, line C) is consistent with the mean of the CEP estimates. This implies that 50 % of the expected earthquakes at UCSB will exceed the current DBE. If the DBE were increased to line B (5% in 50 years earthquake return period) only 16 % of expected earthquakes would exceed this new DBE. That new DBE would be comparable to the + 1 standard deviation of CEP estimates as well as to the UBC 97 code estimates.

used by the CEP: the Rivera Library at UC Riverside, the Thornton Hospital at UC San Diego, and the Engineering 1 building at UC Santa Barbara.

The CEP estimates are obtained by using an integrated geological, seismological, geophysical, and geotechnical approach, bringing together the unique capabilities of the campus and Laboratory personnel. This project is also designed to maximize student participation. Many of the site-specific results are also applicable to risk evaluation of other sites on the respective campuses. Eventually, both the results from the state-of-the-practice and from the CEP should be analyzed, to arrive at decisions concerning the design-basis assumptions for buildings on UC campuses (see figure).

As of July 1999, the Phase 1 studies have been completed at the three target campuses. They include complete seismotectonic studies, site characterization, emplacement of new seismic stations with seismometers at depth up to 300 ft, and acquisition of records from earthquakes on the causative faults, which are the main threats to the campuses. Phase 2 will provide the actual estimates of strong motions, and is expected to be completed in 2000 for all three campuses.

California Center for the Quantum Design and Synthesis of Novel Materials

This program teams LLNL's Materials Research Institute (MRI) and several campuses of UC to establish a focused, statewide initiative in materials physics. The breadth of materials research activities performed mirrors the extraordinary richness and diversity of the field of materials physics itself: from semiconductors to polymers, from metallic alloys to nanostructures, from molecular-beam epitaxy to high-pressure diamond-anvil cell synthesis.

The initial thrusts include studies of growing and characterizing new semiconductor nanostructure systems; using scanning tunneling microscopy to observe surface chemical reactions; synthesizing and characterizing intermetallic silicide and aluminide materials using novel chemical fabrication techniques; and studies of the effects of strains and elastic stability of materials using recently emerging computational tools.

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The Lawrence Livermore Postdoctoral Fellowship Program

In FY98, LLNL's Deputy Director for Science and Technology (DDST) established a prestigious Postdoctoral Program with the goal of attracting the most talented young Ph.D.s in the world to LLNL. This new program was first announced in the fall of 1997 in six professional journals and on Laboratory web sites. The Fellows are selected for three-year-appointment through a selection committee consisting of one representative from each of the Laboratory's scientific directorates. Four hundred twenty applications were received from all scientific disciplines during the first year and 450 applications during the second year. The quality of applicants was extremely high, making this program a source of Post-Doctoral recruitment for the entire Laboratory. Four Fellows were selected in each of the first two years.

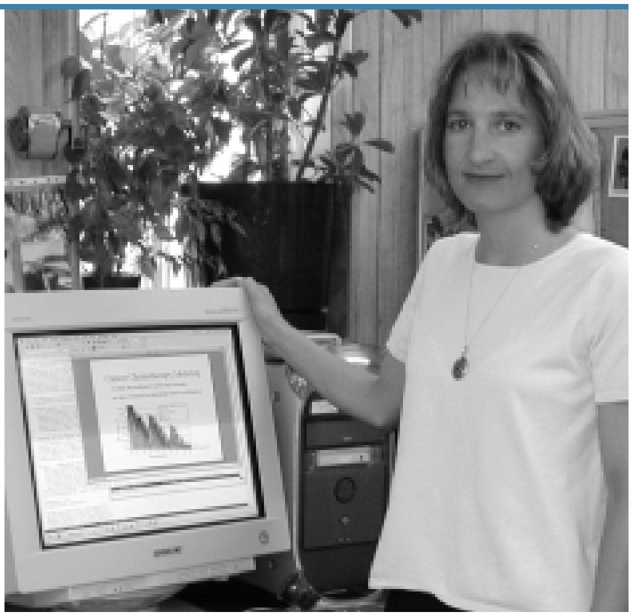
Each Fellow has a senior scientist from his/her discipline directorate appointed as a mentor. These mentors serve as their research guides, help them to make the best use of LLNL's unique facilities, and introduce them to other scientists working on similar problems and to Laboratory educational activities (such as seminars). The Fellows are administratively associated with their mentors' directorates, but do not have programmatic responsibilities. Rather, they devote full time to independent research. The Fellows bring new initiatives, fresh approaches, and a high energy level to the LLNL research environment.

The first four Lawrence Livermore Fellows, appointed in June 1998, were: Nicolas Hadjiconstantinou, Joel Ullom, Aleksandr Noy, and Robert Heeter. The four Fellows selected in June 1999 were: Luc Machiels, Jeffrey Grossman, Shea Gardner, and Andrew Williamson. They started their employment at LLNL during 1999 with the exception of Andrew Williamson, who started in March 2000.

Shea Gardner

Dr. Shea Gardner received her Ph.D. from UC Davis in 1997 in Population Biology. She started her Postdoctoral Fellowship at LLNL in October 1999, with a focus on developing mathematical and computer models of cellular population dynamics and evolution through two projects.

The first of Dr. Gardner's projects is to develop a general model of the evolution of drug resistance in response to multi-drug therapy with different modes of action. The theoretical framework could apply to situations as disparate as pest control, viral or bacterial control, or cancer chemotherapy, although her focus is on cancer. The aim is to develop a tool to tailor chemotherapy protocols for individual patients based on their particular tumor cell characteristics such as the proliferative fraction and the rates of cell division and death. Substantial individual variation in tumor cell population dynamics and responses to therapy suggest that tailoring therapy to individuals may improve the probability of cure and survival times. Questions of interest are: How many and which kinds of drugs are necessary for cure? At what doses and schedules should they be applied? When the model is further along, Dr. Gardner hopes to test it with cell culture experiments, as well as metastatistical analyses of clinical trials that are in the literature. If successful, animal models and clinical trials will be necessary.



Shea Gardner is contributing to LLNL's Biology and Biotechnology Program.

A second project, in collaboration with other LLNL researchers, involves modeling the persistence of chromosome aberrations over time. The persistence of translocations over time has enabled researchers to estimate the dose of ionizing radiation to which a person has been exposed. However, some evidence suggests that translocation frequencies may not remain stable, particularly over the short term. Dr. Gardner is using models fit to empirical data to examine alternative explanations for changes in translocation frequencies.

Jeffrey Grossman

Dr. Jeffrey S. Grossman received his Ph.D. in theoretical condensed matter physics at the University of Illinois in 1996. From Illinois, he went to UC Berkeley as a postdoctoral fellow where he continued to work as a computational condensed matter theorist, tackling projects on materials modeling, reaction path energetics, and superconductivity. In January 2000, Dr. Grossman started research at LLNL as a Postdoctoral Fellow.

The recent ability to prove and manipulate materials on the atomic scale has driven the need for accurate theoretical predictions. Huge advances in technology have further helped to motivate the need to understand a myriad of new complex materials. For example, at the current rate of miniaturization, wires will be as small as 10-50 atoms across within the next decade. These new "nanotechnology" devices have many unique properties that are not yet well understood, making accurate theoretical modeling of this size range crucial.

Jeffrey Grossman's work in modeling molecular systems is expected to lead to advances in nanotechnology.

The goal of Dr. Grossman's search is to expand the applicability of a method known as quantum Monte Carlo (QMC) to treat materials science, chemistry, and biological problems modeled as large molecular systems. Due to the small size of these systems, quantum mechanical effects must be taken into account. At LLNL, Dr. Grossman will use the QMC methodology to make predictions regarding structure, energetics, and optical properties with "chemical accuracy" for a number of systems including combustive reaction processes, biological molecules and novel nanocrystals or quantum dots.

Nicolas Hadjiconstantinou

Dr. Nicolas Hadjiconstantinou received his Ph.D. in 1998 from the Engineering Department of the Massachusetts Institute of Technology (MIT). He joined LLNL as a Fellow in August 1998, deferring a teaching appointment at MIT for one year, to continue his research.

Most of the first six months of Dr. Hadjiconstantinou's Fellowship were spent on the development and exploration of a new simulation tool. This tool is an extension of the Direct Simulation Monte Carlo (for the simulation of dilute gases) to dense fluids. It has enabled the Laboratory to simulate the phase change characteristics of a van der Waals fluid for the first time. This fluid is a very

Nicholas Hadjiconstantinou made important contributions to the development of new simulation tools now in use at LLNL.

famous model in statistical mechanics because it is simple yet effective. The assumptions incorporated in this model make it the first to capture the essentials of a vapor-gas phase transition, which is very hard to simulate. These simulations also allowed the critical confirmation of the van der Waals theory of surface tension.

Dr. Hadjiconstantinou also worked on developing a model for the estimation of the maximum splat diameter of a solidifying droplet. In this problem, droplets of small (millimeter) diameter impact a cold surface and solidify while spreading. Modeling this process is very important for the design of efficient microfabrication techniques.

Dr. Hadjiconstantinou also worked on the simulation of mixing problems involving shock accelerated fluids. These problems are of particular interest to the Laboratory because of their practical importance to the NIF project. The efficiency of ignition is reduced if mixing between the fusion material and the confining structure material occurs. The interface between these two is known to be unstable due to the shock wave acceleration that occurs during the ignition phase. These instabilities grow and lead to mixing of the two materials, and hence potential loss of efficiency.

Robert Heeter

Bob Heeter uses X-ray spectroscopy of photo-ionized plasmas to simulate astrophysical phenomena.

Dr. Robert Heeter completed his Ph.D. degree at the Princeton Plasma Physics Laboratory at Princeton University and began his LLNL Fellowship in 1999. His research interests cover astrophysics, laser-driven plasma physics, and laser applications to biomedical problems. Dr. Heeter is performing laboratory astrophysics experiments to test, for the first time, the behavior of x-ray photoionized plasmas. These conditions only occur near extremely intense x-ray sources such that the ionization of the plasma is dominated by the x-ray-driven processes. One place where such conditions occur in nature is near black holes in active galaxies and neutron stars in x-ray binaries, where matter trapped in a death spiral by the strong gravity releases copious x-rays.

Existing models, however, disagree widely in their prediction and interpretation of the x-ray spectra for photoionized plasmas. To better test the models and thereby improve the reliability of astrophysical data analysis from x-ray telescopes, one would like to produce controlled experiments in the same conditions here on Earth. Neutron stars being difficult to produce in a laboratory, Dr. Heeter and his team from LLNL are instead collaborating with scientists at Sandia National Laboratories-Albuquerque to use the most powerful x-ray source here on Earth, Sandia's "Z Machine," to simulate these conditions. In 1999, Dr. Heeter led the first laboratory experiments to produce plasma conditions scaled to match those found near the neutron stars or black holes. In these experiments small wispy foils made of plastic and the astrophysically significant element iron were placed 15 millimeters from the 120-terawatt pinch, where they were vaporized and heated by the x-rays to temperatures estimated near 1 million degrees Kelvin. Having validated their approach with these preliminary experiments, Dr. Heeter's team is now proceeding with second-stage experiments to obtain the full range of data.

In addition to his current research in photoionized plasma spectroscopy, Dr. Heeter is also actively involved in LLNL's Science and Technology Education Program, with whom he is developing an online "Plasma Dictionary" (http://education-db.llnl.gov/plasma/). He also maintains a major educational Web site on plasma physics and fusion energy (http://FusEdWeb.pppl.gov) which attracts an average of over 3000 hits per day from students, teachers and other scientists.

Luc Machiels

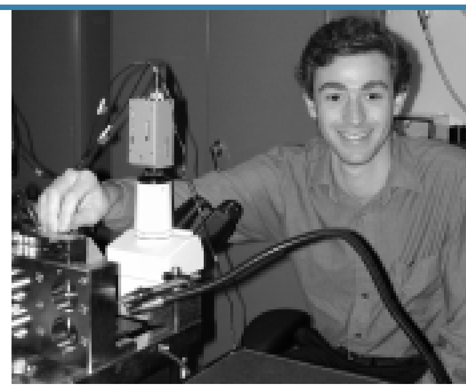
Luc Machiels is working in LLNL's Center for Applied Scientific Computing.

Dr. Luc Machiels, a native of Belgium, received his Ph.D. in 1997 in Mechanical Engineering from the Swiss Federal Institute of Technology in Lausanne, Switzerland. He began his Postdoctoral Fellowship at LLNL in November 1999, after a postdoctoral position at the Massachusetts Institute of Technology (MIT) with a focus on continuum mechanics.

Research in the field of scientific computing for problems of continuum mechanics has been very productive in recent decades. A variety of efficient discretization methods is now available. These methods, in conjunction with advanced computer architectures, permit scientists and engineers to simulate very sophisticated and large physical and industrial systems. Nevertheless, for a wide range of problems, little is known about the fidelity of the numerical solutions since both the physical modeling and the discretization method lead to errors. For these problems, in addition to a good numerical method, the engineer who wants a reliable design and the physicist who wants to assess the validity of a result need quantitative and inexpensive means to evaluate a relevant measure of the error (or at least, means to reduce the uncertainty associated with the error). Dr. Machiels' research aims at providing such means and, when possible, a technique to control (reduce) the error.

Recently, in collaboration with Profs. A. T. Patera and J. Peraire of MIT, Dr. Machiels has developed a new finite element error control strategy for the incompressible Navier-Stokes equation. The technique calculates lower and upper bounds for an output of the system, such as the temperature on the surface of an electronic device. These bounds are inexpensive to compute, rigorous, quantitative, sharp, and permit optimal adaptive mesh refinement. Therefore, scientists are no longer compelled to choose either certainty or efficiency; both can be achieved. The methodology can also be applied to a variety of other situations including elasticity, the Helmholtz equation, eigenvalue problems, and time dependent (parabolic) problems. Dr. Machiels has recently developed an output bound technique for iterative solution of partial differential equations, and is working on the application of the method to reduced-order models of partial differential equations.

Aleksandr Noy



Aleksandr Noy with high-resolution topographic imaging equipment.

Dr. Aleksandr Noy received his Ph.D. in 1997 from the Department of Chemistry and Chemical Biology at Harvard University. He remained at Harvard as a Postdoctoral Researcher for one year before joining LLNL as a Fellow.

Biology and biomaterials have been identified as future important directions for LLNL research. Progress is ultimately determined by our ability to gather detailed information about biological processes on the molecular scale. To understand the interactions of small molecules such as drugs, mutagens, and messenger molecules with proteins, cell membranes, mineralized tissue and DNA, it is necessary to spatially map and study biologically relevant surfaces. Dr. Noy is studying how small molecules interact with the surfaces of biological materials and is developing new methods to investigate these interactions on a molecular scale.

Methods to achieve these goals have to satisfy several important conditions. They must be able to work in liquids under ambient conditions (or even in-vivo), must be sufficiently non-destructive to allow continuous monitoring of processes, and must also have distance and force resolutions compatible with the scale of interactions (i.e., ~1-10nm spatial resolution and 100 pN force resolution). Scanning Probe Microscopy (SPM) allows one to image molecular species on that length scale. Since SPM couples the necessary resolving power with the ability to work in a variety of environments, it presents an ideal technique for studies of biomaterials. Its combination with the optical techniques, such as fluorescent detection, allows one to get a comprehensive picture of a biomolecular process.

Dr. Noy is designing and building an instrument that would combine scanning probe microscopy functionality with the single-molecule-level optical detection to satisfy the requirements outlined above. He is also co-PI on a number of projects that aim to develop capabilities for high-resolution imaging and force measurements that would be complementary to the current effort in instrument development.

Joel Ullom

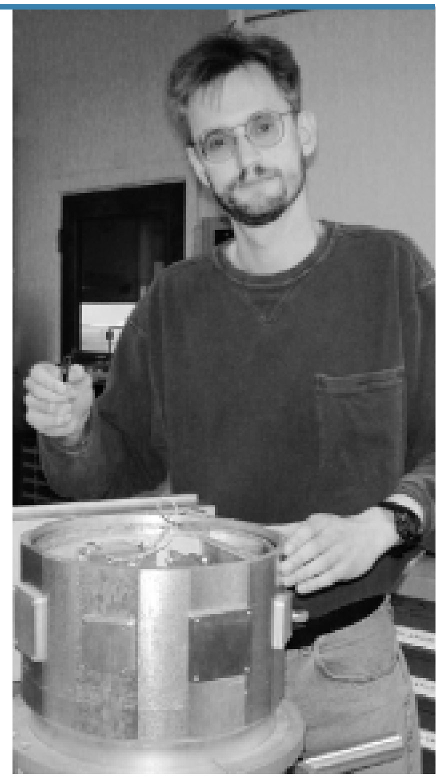
Dr. Joel Ullom received his Ph.D. from Harvard University in December 1998 in Low Temperature Solid State Physics. He immediately began his Postdoctoral Fellowship at LLNL in January 1999.

Dr. Ullom's work at LLNL is focused on the development of cryogenic detectors and finding novel applications for these devices. A cryogenic detector is a small electrical circuit, usually much smaller than a square millimeter, which produces a current or voltage pulse in response to an impacting photon or particle. To work properly, these devices must be cooled to temperatures between 0.1 and 1 degree Kelvin. At these extremely low temperatures, the energy of a single photon can produce significant heating in a small piece of material. This heating is then converted to an electrical signal by the detector. Cryogenic detectors often incorporate a superconducting material. When extreme heating disrupts the superconductivity, it causes an abrupt appearance of electrical resistance. In moderation, heating creates electronic excitations in a superconductor, and the motion of these excitations, called quasiparticles, can be measured as an electrical current.

The cryogenic detectors' ability to detect individual photons and determine the energy of a photon with great precision has a number of applications. For instance, the identity of contaminants on a silicon wafer can be determined by irradiating the wafer with an electron beam and measuring the energy of the fluorescence x-rays. Not only can cryogenic detectors sense x-rays, they can also detect the impact of ions. A recent development in the field has been to observe the motion of very heavy molecules by first launching them from a substrate at a known time and then registering their impact on a cryogenic detector. The mass of the molecule can be deduced from the travel time so the detectors are, in effect, being used to weigh the molecules.

Dr. Ullom is currently using cryogenic detectors to weigh the protein fragments dislodged from bacterial spores by a pulse of laser light. The size of the fragments is characteristic of the bacterial species so it is hoped that this work will have biomedical applications. The project is a collaboration of a number of individuals at LLNL and Lawrence Berkeley National Laboratory (LBNL). Dr. Ullom is also developing new refrigeration technology to produce the ultra-low temperatures needed for cryogenic detectors.

By exploring new detector applications, new detector concepts, and new refrigeration techniques, the LLNL Postdoctoral Fellowship has allowed Dr. Ullom to do basic science and develop technology that one day may be commonplace in research laboratories, factories, and even hospitals.



Joel Ullom standing by a refrigerator used to cool to .07 degrees above absolute zero.

Andrew Williamson

Andrew Williamson's research focuses on quantum dots.

Dr. Andrew Williamson received his undergraduate degree in Natural Sciences from the University of Cambridge, UK, in 1993. He remained at Cambridge conducting his graduate work in the Theory of Condensed Matter Group in the Cavendish Laboratory. Dr. Williamson's graduate research centered on developing sophisticated computer simulations of the electronic properties of semiconductor materials such as silicon and germanium. He received his Ph.D. in Physics from Cambridge in 1996.

Upon completion of his Ph.D., Dr. Williamson accepted a postdoctoral research fellowship at the National Renewable Energy Laboratory (NREL) in Golden, CO. During three years at NREL, he used his knowledge of semiconductor materials to perform computer simulations of different material structures being examined as candidates for the next generation of solar cells. One of the candidates studied was a class of materials formed by linking together millions of tiny particles called quantum dots. Each quantum dot has a typical size of 10 nanometers, about 100 times smaller than the width of a human hair. As a result of their tiny size, quantum dots have a unique set of physical properties that can be harnessed to dramatically improve the efficiency of solar cells.

During his Livermore Fellowship, Dr. Williamson will continue his research into the properties of quantum dots. He plans to develop a deeper understanding of how the unique properties of quantum dots depend on their size, shape and composition. A study of such small particles requires sophisticated quantum mechanical simulation techniques that describe how individual electrons in the quantum dots interact with each other and with external probes such as lasers. These simulations are extremely computationally intensive, and Dr. Williamson will make extensive use of the supercomputer resources available at the Laboratory. There are also several experimental groups within LLNL who are world leaders in the synthesis of quantum dots. These groups are measuring the optical properties of quantum dots to try and gain more information on their structure. Dr. Williamson will work closely with these LLNL researchers to use his simulations to interpret their results and to propose new experiments.

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Research Collaborations Program for Historically Black Colleges and Universities and Minority Institutions

The LLNL Research Collaborations Program (RPC) for Historically Black Colleges and Universities (HBCUs) and Minority Institutions (MIs) is a Laboratory-wide program which fosters productive and mutually beneficial technical interactions between LLNL and the nation's HBCUs and MIs.

The principal goals of the Program are to develop research collaborations that link accomplished faculty members with LLNL scientists in research supporting DOE and LLNL programmatic missions, and to help train students by giving them access to the most advanced research methods available.

The collaborations to date have involved eleven Historically Black Colleges and Universities (HBCUs) and two Minority Institutions (MIs). Participants include students as well as post-doctoral researchers and professors. LLNL scientists from six directorates have participated. Some collaborations also involve scientists from other institutions, including UC Davis and Sandia National Laboratories/California.

These collaborations span a wide spectrum of research interests. Some of the projects involve numerical calculations or computer simulations, others are experimental and have made use of LLNL facilities such as the Electron Beam Ion Trap (EBIT) Facility.

Jason Collins, Clark Atlanta University (left), and Dr. Howard Lee, LLNL, in Photonics Laboratory at LLNL.

By linking accomplished HBCU and MI faculty and students with LLNL, the Research Collaborations Program (RCP) maximizes the benefits to both the Laboratory and the participating academic institutions. The HBCU and MI partners enhance their research and training capabilities through access to the unique facilities and expertise at LLNL. They gain greater visibility in nationally recognized scientific endeavors and improve their ability to attract funding as well as quality students and faculty. The HBCU and MI partners also benefit from opportunities to network with other institutions connected with LLNL.

The Laboratory also benefits from the Program. The participating faculty, post-doctoral researchers, and students provide additional manpower and expertise for basic research and allow LLNL to leverage its unique facilities to help maintain critical core competencies. The Program has also opened a valued channel for training and recruiting potential Laboratory employees from among HBCU and MI students.

Student involvement is a critical component of RCP. The Program enables undergraduates and graduate students from HBCUs and MIs to have meaningful and enriching research experiences at LLNL and on their home campuses. In FY98, thirty-two students participated in joint projects and thirty in FY99. By enhancing the research capabilities of the schools and supplementing their educational efforts in the sciences, RCP positively impacts the training of Minority students in scientific disciplines. Student participants have presented their research at professional conferences and university symposia. Some have coauthored publications in major refereed scientific journals. Participation in RCP has motivated a significant number of students to pursue advanced degrees. More than twenty participants have entered graduate programs in the physical sciences. The active projects in FY 1998-99 included:

- Nonlinear Optical Absorption in KDP Crystals (City College of New York)
- Theoretical Studies of Energy Coupling in Hot Dense Plasmas (Howard University)
- X-ray Spectra for Laser Fusion Diagnostics (Morehouse College)
- Development of Tunable Mid-Infrared Lasers (Fisk University)
- LIDAR for Remote Sensing and Atmospheric Studies (Howard University)
- New Materials for Fiber Optic Gas Phase Sensors (Southern University)
- Free-Standing Quantum Wells (Clark Atlanta University)
- Dissociative Recombination of Rare Gas Molecular Ions (Florida International University)
- Studies of Organic Opto-Electronic Crystals (Alabama A&M University)
- Time-Dependent Wave Packet Theory for Electron-Molecule Scattering (Florida A&M University)
- Studies of CP Violation at the SLAC/LLNL/LBNL B-Factory (Prairie View University)
- Engine Turbulent Signatures for Reactant Mixing Manipulation (Florida A&M University)
- Wavelets for Geophysical Logs (Spelman College)
- Novel Temperature Diagnostic for High Explosives (Alabama A&M)

In addition to research at LLNL in the summer, the collaborations continue throughout the academic year on campuses and at the Laboratory. Campus research is supported through contracts with the universities. RCP also works with the DOE Oakland Operations Office to provide grants that cover student stipends and release time for professors for work done on the campuses. RCP makes use of the existing research facilities and capabilities at the universities and also facilitates computer and equipment loans to help with research on the campuses. In addition, LLNL scientists travel to the universities to present seminars and conduct research on campus.

Work in six of the collaborations is described in the following examples:

Fisk University

The collaboration with Fisk University is an investigation of optical materials for a new class of tunable solid-state mid-infrared wavelength lasers, based on Cr-doped ZnSe and related materials. Growth and doping of the materials is carried out in the NASA-supported photonics laboratories at Fisk. Characterization of these materials is done in the laser facilities at LLNL. The technology of diffusion-doping of Cr_2^+ into ZnSe and ZnS crystals was first introduced to LLNL by Fisk through RCP. The joint effort led to a significant reduction in detrimental losses in the crystals and thereby to increased laser efficiency. This is an example of an RCP collabora-

"The diffusion doping concept and expertise brought by the Fisk team was a very important contribution. . . . This has been a very good collaboration."

Steve Payne, Associate Program Leader for Laser Technology Development at LLNL

Daniel Felten (graduate student from Howard University) at the Ultra-Short-Pulse-Laser Facility at LLNL.

tion making a major contribution to an LLNL technical program.

Another striking indication of the success of this collaboration is that Cr-doped ZnSe is becoming a commercial laser material. The commercial suppliers are interested in using the Fisk concept.

Morehouse College

LLNL collaborates with Morehouse College in research using the LLNL Electron Beam Ion Trap (EBIT) Facility. The LLNL Principal Investigator and the Morehouse Principal Investigator have submitted joint proposals to several agencies. In FY98, the DOE Office of Basic Energy Sciences funded one of these proposals.

Through the RCP collaboration, the Morehouse PI connected with a professor at Auburn University (a majority institution in Auburn, Alabama) who is also a collaborator on EBIT. Their interaction at LLNL led to the transfer of equipment from Auburn to Morehouse, and to the construction of a vacuum spark apparatus at Morehouse. As a direct result of the RCP, there is now a plasma device at Morehouse making atomic physics and x-ray diagnostics studies possible on that campus.

Florida International University

In our collaborative work with Florida International University (FIU), an Hispanic Serving Institution (HSI), the first observations and measurements of dissociative recombination of He_2^+ were accomplished. This work was reported at the Gordon Conference on Atomic Physics and at the Fourth International Conference on Dissociative Recombination, held in Stockholm, Sweden, in June 1999. A manuscript on this work was published in *Physical Review Letters* and includes the FIU professor and an FIU student as co-authors. The Physics Department of FIU was granted approval to start a Ph.D. program, and the FIU Department Chair sent a letter to the Laboratory acknowledging the critical role that LLNL's RCP played in bringing the University's research program to a level that warranted a Ph.D. program.

Howard University

In FY98, a grant for Inertial Fusion Science Supporting Stockpile Stewardship was awarded to a Howard University professor working with RCP on High-Energy-Density Studies at the LLNL Nova Facility. There were only 14 grants awarded nationwide, and the Howard project was the only HBCU or MI recipient.

Dr. John Molotoris, LLNL (left), Eric Davis, LLNL (center), and Ahmed Farah, Howard University (right).

This grant supports the work of the professor and helps with the training of students in research areas relevant to Stockpile Stewardship.

A different group at Howard University received an LDRD feasibility study award for a project utilizing LIDAR with the telescope at the Howard University Atmospheric Observatory.

City College of New York

A team of LLNL scientists is working with faculty and students at City College of New York (CCNY), an HSI, on a study of two-photon absorption in optical materials that will be used in the high power lasers for the National Ignition Facility (NIF). While the linear losses of UV lasers are well characterized and correlated with impurities in optical materials, the nonlinear losses due to high-fluence laser pulses are not well characterized, and the origin of the nonlinear losses is not yet well understood. This research addresses these issues, and the results can be important for NIF. The collaboration uses the National Science Foundation (NSF)-supported nonlinear optics laboratory at CCNY, and the optical crystal growing facilities at LLNL. The students participating in this program are acquiring experience and practical training in laser technology, nonlinear optics, crystallography, and spectroscopy. This collaboration has already demonstrated that nonlinear losses can be correlated with impurities in KDP crystals.

Alabama A&M University

A project on Rare-Earth Doped Crystalline Matrices for Novel Temperature Diagnostics of High Explosives

Lisa Hill, Clark Atlanta University, and Dr. Peter Beiersdorfer, LLNL, at the LLNL Electron Beam Ion Trap Facility.

engages a professor and students from Alabama A&M University (an HBCU) with a group from LLNL's Defense and Nuclear Technology Directorate. The next generation of weapons simulation codes for the Stockpile Stewardship Program will require advances in the spatial and temporal resolution of various diagnostics to verify the complex physics predicted from these calculations. The team plans to test a new concept developed at LLNL with rare-earth doped organic and inorganic crystals, which will be grown at the Optical Materials Laboratory at Alabama A&M. This laboratory is part of an NSF-supported Center of Research Excellence in Science and Technology (CREST). Characterization and evaluation of the crystals will be carried out in the facilities at Alabama A&M and also at LLNL. The participating students will receive training and experience in research on HE, and practical training in growth and doping of optical materials, optical luminescence techniques and electron spin resonance studies.

Publications and Presentations

During the period FY98-99, professors and students in the Program submitted or published 25 papers in scientific journals, and delivered 46 presentations at seminars, symposia and conferences. Colm Mulcahey (Spelman College) and Farid Dowla (LLNL) jointly organized and chaired a symposium entitled "Wavelets: The Latest Big Splash in Science, Engineering, Imaging and Graphics" at the annual American Association for the Advancement of Science (AAAS) meeting in February 1998. Their collaborative work on wavelets was supported by the LLNL RCP. Student posters on RCP collaborations received First Prize at the DOE-EPSCoR Symposium in Baton Rouge, LA, in March 1999, and Honorable Mention at the US DOE-FETC-HBCU Symposium in Miami, FL, that same month.

The Future

In FY2000, The RCP will continue collaborations that engage HBCUs and MIs with LLNL in significant and mutually beneficial research and will continue to encourage students in the program to pursue graduate degrees in the physical sciences. The Program will also cultivate new collaborations with HBCUs and MIs in the area of astrophysics and space science and will explore possibilities for partnering with appropriate outreach programs at the UC campuses.

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National Physical Science Consortium

NPSC's mission is to increase the number of qualified minorities and women with graduate degrees in the physical sciences.

The National Physical Science Consortium (NPSC) is a network of universities, national laboratories and private industries united for the purpose of increasing scholarships and broadening career paths for graduate students in the physical sciences. Though open to all qualified applicants, the NPSC places primary emphasis on recruiting women and under-represented minorities (African American, Hispanic, Native American, Eskimo, Aleut and Pacific Islander).

It is well known that U.S. demographics are shifting dramatically. According to the last U.S. Census, from 1980 to 1990 the U.S. population increased by 9.8%. During that period, the African American population increased by 13.2%, Hispanics by 53% and Native Americans by 37.9%. Currently, two-thirds of the overall population and 57% of the workforce is female, minority, or both. The U.S. Census Bureau predicts by the year 2050, the population will be 53% White, 23% Hispanic and 14% African American, with 10% of the population representing other ethnic groups.

In spite of this continuous population growth, there is a projected shortage of U.S.-citizen physical scientists in both industry and academia over the next decade. The previous predominant reliance on white males is not an alternative. The National Research Council's statistics reflect that of the 6,675 physical science Ph.D.'s graduated in 1996, only 51.6% were U.S. citizens. Of the graduating U.S.-citizen Ph.D.'s in science and engineering, 33% were women and only 5.1% were minorities—African American, Hispanic, and Native American.

The new pool of future scientists must be drawn from the minority and female population. Foreseeing this trend a few years ago, a national task force was formed to address the growing national shortage of minorities and women in the physical sciences. The task force recommended establishing the National Physical Science Consortium (NPSC), which was incorporated as a nonprofit organization in California in December 1987. The National Science Foundation, Lawrence Livermore National Laboratory (LLNL), and the U. S. Department of Energy provided the NPSC's initial funding. The NPSC is now self-supporting, funded by annual membership fees received from employer members.

The Consortium currently consists of 125 colleges and universities and 40 sponsoring employers, including alliances with the Navajo Nation and the Hispanic Association of Colleges and Universities (HACU). The NPSC's Headquarters Office is on the University of California-San Diego campus and the Student Recruitment Office is located on the New Mexico State University campus.

NPSC offers a unique combination of substantial financial aid, quality research experience, and effective mentoring. The mentoring system offers the opportunity for individuals to network with leading researchers, universities, employers and other NPSC Fellows. The Consortium granted its first fellowship awards in 1989 to seven students. The program is now in its 11th year and has had 52 Ph.D. graduates from a total of 245 Fellows. There are presently 110 Fellows in the Program. The internal breakdown is 51% minority and 49% non-minorities—of which 74% of all Fellows are female. NPSC currently has a 90% retention rate of its Fellows.

LLNL is an active participant in the NPSC program. The Laboratory is currently supporting 16 students in many fields of science and technology. The University Relations Program coordinates the Laboratory's participation in the NPSC, including placing students at LLNL.

LLNL Participation in the National Physical Science Consortium FY 1998-99

Student	Affiliated University	Academic Field	LLNL Host Organization
Lora Ballinger	University of Utah	Mathematics	Computations (ISCR)
Bridget Bergquist	Massachusetts Institute of Technology	Environmental Science	Earth and Environmental Sciences (CAMS)
Kerri J. Blobaum	Johns Hopkins University	Materials Science	Chemistry and Materials Science
Anita Bowles	Harvard University	Physics	Physics
John Cavazos	University of Massachusetts	Computer Science	Computations
Trevor Clark	Stanford University	Materials Science and Engineering	Chemistry and Materials Science
James C. Espinosa	University of Texas	Physics	Physics (IGPP)
Jennifer Glass	UC Berkeley	Physics	Lasers
Heileen Hsu	UC Berkeley	Geoscience	Earth and Environmental Sciences
Rachel Karchin	UC Santa Cruz	Computer Engineering	Computations (ISCR)
Diana Marie (Franklin) Keen	UC Davis	Computer Science	Computations
Imelda J. Kirby	University of Washington	Bio-Physics	Computations (ISCR)
Carla Levy	Harvard University	Physics	Physics
Christophe McCray	Hampton University	Physics	Lasers
Shannon McDaniel	University of Washington	Geophysics	Physics
Cailin Nelson	UC Berkeley	Physics	Physics (IGPP)
Iwona Palusinski	University of Arizona	Optical Sciences	Lasers
Norma Pawley	Cornell University	Physics	Earth and Environmental Sciences (CAMS)
Amy Perkins	Brown University	Physics	Lasers
Joseph Phillips	University of Michigan	Computer Science	Lasers
Tamara Rogers	UC Santa Cruz	Astrophysics	Physics
Megan Thomas	UC Berkeley	Computer Science	Computations (ISCR)
Marlon Veal	UC Santa Cruz	Computer Science	Earth and Environmental Sciences
Lisa Wickham	Cornell University	Physics	Physics
Shara C. Williams	UC Berkeley	Chemistry	Chemistry and Materials Science

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Science & Technology Education Program (STEP)

The Science & Technology Education Program (STEP) augments the Laboratory's education goals and program content through targeted educational projects.

STEP Internship and Outreach Programs

Lawrence Livermore National Laboratory's Science & Technology Education Program (STEP) serves as a resource to students, teachers, and faculty by facilitating research opportunities with the Laboratory's scientific facilities and staff. STEP also supports the science education needs of the local and regional communities surrounding LLNL.

STEP leads the Lab's science education activities that:

Middle-school and high-school students from the communities surrounding the Laboratory are provided the opportunity to attend one of three Expanding Your Horizons conferences each year. In FY99 about 1,600 young women attended the three conferences where technical careers are discussed using workshops within various science topics.

- Facilitate research internships for college students entering careers important to the intellectual capability required by the LLNL and DOE national security mission, and also
- Enhance science literacy and science education activities through technical partnerships with the education community.

A common theme of the science education projects within STEP is the integration of research and education at all school levels: pre-college, undergraduate, graduate. This integration, along with career counseling, is accomplished by having the science education activities take place within the Laboratory's research activities.

Internship Projects

STEP facilitates partnerships and collaborations with the education community to help ensure a highly-skilled, diverse workforce for the science and technology challenges within the national security mission needs of the U. S. Department of Energy (DOE).

Individual internship projects fall within the Laboratory's mission-based science programs. These education projects engage college students within the disciplines of computations/simulation, physics, chemistry/materials science and engineering.

The underlying goal of STEP projects funded by DOE's Defense Programs (DP) is to support the long-term workforce and core-competency needs of DOE-DP programs related to national security.

As with the Laboratory's research, STEP's DP science education program is conducted in many circumstances as a collaboration between LLNL and the other DOE-DP national laboratories – Los Alamos National Laboratory (LANL) and Sandia National Laboratories (SNL).

Outreach Projects

STEP motivates pre-college students to consider a college education as part of their future career choices. These pre-college science literacy activities play an important role in the creation of future scientists, engineers, and technicians by enlightening students to potential careers in science and technology, especially those of special interest to LLNL and DOE. These outreach projects are funded by the LLNL General and Administrative (G&A) Distributed Budget.

Teacher Projects

Through local and regional education partnerships, STEP leads the Laboratory's education efforts to stimulate greater interest in science and technology among teachers and administrators, and to encourage more students to pursue scientific and technical careers after high school. Such an education outcome is important to the economic security of our nation so that the United States can compete successfully in the world marketplace.

Internship Projects – Major Accomplishments in FY98 and FY99

Exposing students to scientific research and scientific careers will increase the number of successful students who choose careers of importance to the LLNL and DOE science and technology mission. Therefore, STEP offers numerous internships to undergraduate and graduate students that provide opportunities to become part of LLNL's world-class workforce and to use the Laboratory's state-of-the-art facilities.

Actinide Sciences Summer School Program (ASSSP)

Actinides are radioactive metallic elements in group IIIb of the Periodic Table such as plutonium, uranium and americium. The recruitment of young scientific and engineering talent skilled in this unique field is critical to the long term mission of LLNL and DOE. The ASSSP, designed to help meet this need, hosted 20 participating students at LLNL in FY 98-99. The LLNL ASSSP has been included as an educational credit through the MIT Nuclear Engineering Dept. (FY99), and there are plans for similar credit from the Chemistry Department at UC Berkeley.

STEP Projects in FY98 and FY99

Student Internship Projects
· Actinide Sciences Summer School Program (ASSSP) · ASCI Jr. Capstone Research · ASCI Pipeline - Cal. State University Hayward · ASCI Pipeline - Northern Arizona University · Critical Issues Forum (CIF) · Military Academy Research Associates (MARA) · National Security Cooperative Program (NSC) · Undergraduate Research Semester (URS)
Student Outreach Projects
· Classroom Speakers' Bureau · Expanding Your Horizons (EYH) · Explorer Post · Fun with Science (FWS) · Future Scientists and Engineers of America (FSEA) · Math Challenge · Science on Saturday (SOS) · Tri-Valley Science and Engineering Fair (TVSEF)
Teacher Projects
· Technology Resource Center (TRC)

STEP Participants in FY98 and FY99

	FY98	FY99
Student Internship Projects		
Pre-college	104	124
Undergraduate	96	214
Graduate	30	46
	230	384
Student Outreach Projects	10,920	11,895
Teacher Projects	2,015	883
Total Students and Teachers	13,165	13,162

Accelerated Strategic Computing Initiative/Northern Arizona University (ASCI/NAU) Jr. Capstone Program

The goal of the ASCI/NAU Program is to increase the numbers of Native Americans and other minorities working in high-performance, computer-based modeling and simulation which could be available for future employment at LLNL or throughout the DOE Complex. 120 students participated in ASCI computer topics at Northern Arizona University through a Jr. Capstone course (FY99).

ASCI Pipeline Program

The ASCI Pipeline Program recruited nine NAU students for summer 1999 employment. Five of the students were participants from the six ASCI-PAthways Leading to Success (PALS) programs. Of the remaining four students, three participated in the NAU Jr. Capstone class (FY99).

Critical Issues Forum on Nonproliferation, Arms Control, and International Security (CIF)

Two schools participated in the Critical Issues Forum Program designed to provide opportunities for students and teachers to develop and apply critical thinking and problem solving skills to a complex problem (FY98). STEP worked with Drs. Clay Bowen and Amy Sands from the Monterey Institute of International Studies to develop the West Coast implementation of CIF (FY99).

George Sakaldasis, of the Laboratory's National Security Office, at the LLNL ROTC Day, FY99.

Military Academic Research Associates (MARA)

Cadets and midshipmen from military academies spend their summers working on DOD/DOE national security research. MARA participants expansion included cadets from West Point and the U.S. Naval Academy. Participation grew from five cadets in FY97 to 23 in FY98 and 30 in FY99.

National Security Cooperative (NSC)

Approximately 48 students participated in the National Security Cooperative Program. Research Internships for Education funded stipends in collaboration with LLNL research departments for 25 of these internships. An electronic bulletin board was developed to facilitate networking among student interns (FY98).

Undergraduate Research Semester (URS)

The URS Program provides unique and challenging off-campus research opportunities for upper-division university undergraduate students in science, math and engineering. This is a collaborative effort with the Los Alamos National Laboratory (LANL) and Sandia National Laboratories (SNL), both Albuquerque and Livermore. A total of 35 students participated in the 17-week research seminar at LLNL in FY 98-99.

Four of our outstanding fall 1998 Undergraduate Research Semester Program students were selected to participate in the National Conference on Undergraduate Research (NCUR) at Salisbury University in Maryland. These students were selected to participate in the Council on Undergraduate Research Second Annual Undergraduate Poster Session on Capital Hill. While in Washington, they met with their State's Representatives to promote the value of undergraduate internship programs at the national laboratories (FY98).

Optical Society of America (OSA)/LLNL Student Chapter — Laser Science Summer School Program (LSSSP)

OSA Student Chapter was formed to initiate students to participation as members of a professional society. The president of OSA, Professor Anthony Seigman, visited the LLNL chapter to recognize the value of the LSSSP and to review student accomplishments (FY99).

Outreach Projects – Major Accomplishments in FY98 and FY99

STEP's education outreach efforts at LLNL are designed to address requests from the education community, as well as the public. Program audiences encompass everyone from students, parents, and teachers to organizations and businesses. Through STEP activities, the Laboratory's and DOE's research and development efforts in science, engineering and technology are showcased and public awareness is raised.

Some of these efforts depend primarily on volunteers throughout the Laboratory who are supported by their management. The Science & Technology Education Program staff provides additional support. In classrooms and at special events and workshops, volunteers conduct presentations, demonstrations and discussions centered on Laboratory expertise and core competencies in science and technology.

During FY98 and FY99, over 100 newspaper articles about the Lab's Science Literacy and Education Outreach activities appeared in LLNL *Newsline* and various local newspapers.

Fun with Science

Informal, hands-on science experiences for students, teachers, parents and public groups are offered through this program. Activities are conducted by a number of volunteers from throughout the Laboratory with a goal of encouraging and motivating students' interest in the sciences.

Fun With Science (FWS) volunteers visited 28 schools and/or community events at which a total of 4,160 K-12th grade students participated (FY98).

Classroom Speakers Bureau

STEP responded to 41 requests for volunteers to represent LLNL at school and community events, with 3,150 participants (FY98).

Expanding Your Horizons (EYH)

The EYH Program provides an informal science experience for young women, traditionally under represented in the sciences, and encourages them to pursue careers in science and technology.

About 2,550 young women attended five Expanding Your Horizons conferences co-sponsored by LLNL in FY98 and FY99.

Explorer Post

Explorer Post membership increased to 71 high school students in FY99 from 34 in FY97. The Treasurer of the Explorer Post was awarded $10,000 in a national science competition for his invention of an electro-optic, color-matching system for the visually color impaired (FY99).

Future Scientists and Engineers of America

Five workshops were held for principals, teachers, and mentors interested in Future Scientists and Engineers of America (FY98). A total of 150 participants from six schools participated in FSEA after-school science clubs (FY99).

Math Challenge

Fifty high school students, representing nine high schools, participated in the Math Challenge event co-sponsored by STEP (FY98).

Science on Saturdays (SOS)

Science on Saturdays is a six-week series of free 90-minute talks geared toward middle- and senior-high-school students. The series, which began in 1996, has proven to be tremendously popular, drawing more than 300 people from throughout the Bay Area to each lecture (FY98 and FY99).

Sixteen Science on Saturdays presentations were offered to an audience of 4,075 students, parents, and teachers. The topics ranged from super-fast computers to highlights from the Mars Pathfinder (FY98 and 99).

Tri-Valley Science and Engineering Fair

A total of 225 students participated in the fair, and two first-place winners also took fourth place at the International Fair (FY99).

Teacher Projects – Major Accomplishments in FY98 and FY99

A major goal of STEP is to use technology to support our science education activities. STEP supports pre-college teacher enhancement and curriculum improvement in science and technology to address the overall "pipeline" issue. In support of this goal, STEP projects emphasize creative thinking and the problem-solving skills necessary for successful careers in science, mathematics, engineering, and technology disciplines.

STEP summer teacher Laura Seeley, Monte Vista High School, Danville, CA.

"The District felt that it was important enough to send teachers to intern at LLNL that we found funding. We feel that these internships were a great investment. Both teachers developed new skills that made their teaching more relevant because they were able to introduce new technology from the LLNL experience into their instruction."

Stan Hitomi, Administrator/ Science Teacher Monte Vista High School, San Ramon Valley School District, Danville CA.

Technology Resource Center (TRC)

The Technology Resource Center is offered to participants in the California Technology Assistance Project (CTAP) to provide schools with in-service instruction to faculty. CTAP and the TRC have the goal of preparing teachers to use computer technology as a tool to support integrated instruction. In FY98, 487 teachers, out of a total of 2,015 registered teachers who attended technology workshops, participated as part of in-service technology training.

The Future

STEP will continue with its dual role of managing LLNL efforts in facilitating research interactions of students, teachers, and faculty with the Laboratory's scientific facilities and staff, and supporting the science education needs of the local and regional communities. Having both of these areas of the Laboratory's education initiatives within the STEP organization reflects the recommendations defined by the Task Force on Education of the DOE's Secretary of Energy Advisory Board (December 2, 1998), which stated:

"The Task Force believes the Department's mission justifies its dual role in educating future scientists, as well as in improving the public understanding of science: (1) Ensuring a steady flow of scientists directly supports the Department's mission of maintaining a well-trained future laboratory workforce. Students with scientific aptitude should have opportunities at the Department's national laboratories and facilities where they can obtain the specialized research skills and hands-on experience working on projects that are unique to government research and development.

(2) It is also in the Nation's best interest for the Department to use its resources to enhance public understanding of science. Citizens who have knowledge of science and technology are better-informed voters. The effect is to raise the quality of decision-making and of understanding and support for the Department's multifaceted programs and projects. Everyone learns math and science in grade school, and at this level teachers have an impact on both potential scientists and average students."

The first of the two recommendations falls within STEP's Internship Program, and the second falls within STEP's Outreach Program. In the area of DOE-DP-funded "Internship Projects," there will be even more emphasis at the undergraduate and graduate student level. Student and faculty participants will be further aligned with the critical-skills, workforce needs identified by the Commission on Maintaining U.S. Nuclear Weapons Expertise. (Chiles Report, March 1, 1999)

In the area of the Laboratory's G&A-funded "Outreach Projects," there will be additional partnerships formed with the education community to further align activities with the new science standards of the State of California. Through partnerships with the education community, STEP will assist the education community in its quest for new sources of funding.

STEP will continue to interact closely with other LLNL education activities managed within the Laboratory but funded by other sources. While the STEP Web site is continually updated to reflect the status of its education activities, the banner will remain the same in FY00 as it has in previous years, "Science Education in the National Interest."

Students attending Fun with Science Day for Laboratory employees.

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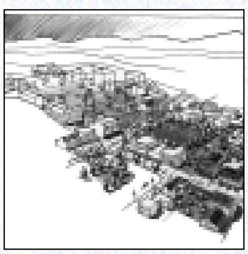

Liaison

In addition to direct programmatic activities, URP serves as the focal point for extensive university collaborations which may not involve direct line management responsibilities. URP's role is to facilitate LLNL-university interactions and to provide support where appropriate.

The Glenn T. Seaborg Institute of Transactinium Science

University of California Davis Department of Applied Sciences

Student Policy Committee

Partnership for Environmental Technology Education

University of California Merced Planning

The Glenn T. Seaborg Institute for Transactinium Science

Background

Transactinium Science refers to the chemistry and physics of elements with atomic numbers greater that 89, such as plutonium and uranium. In addition to basic chemistry and physics, research in this area includes metallurgy, reactivity and fate and transport studies.

The Glenn T. Seaborg Institute for Transactinium Science (GTS-ITS) was established in 1991 when UC approved a joint LLNL/Lawrence Berkeley National Laboratory (LBNL) Institute Charter. In 1997, a branch was also established at the Los Alamos National Laboratory (LANL). The mission of GTS-ITS is to provide a focus for transactinium science to maintain and enhance U.S. leadership in this science and technology, and to help provide the required pool of scientists and engineers of the quality and breadth necessary to meet changing national and international needs in the future. The Institute supports the long-term human resource and core competency needs of the defense-related and environmental programs at LLNL and the Department of Energy (DOE).

The 1998 ASSSP students with Professor Glenn T. Seaborg.

GTS-ITS Actinide Sciences Summer School Program (ASSSP)

The purpose of the ASSSP is to provide education and research training in transactinium science for undergraduate and graduate students. The intent of this program is to encourage students to pursue scientific careers in general, to give them exposure to the actinide sciences and to encourage them to consider career fields that lie at the heart of the DOE nuclear mission. It is particularly aimed at undergraduate students who have shown an interest in the field of nuclear science and have attended the Nuclear Radiochemistry Summer Schools at San Jose State University and Brookhaven National Laboratory. These schools are funded by the (DOE) and sponsored by the American Chemical Society. Student participants in ASSSP are partnered with laboratory scientists on research projects where they are offered hands-on experience with plutonium and other actinides and receive training in the use of state-of-the-art research equipment.

In the summer of 1998, in partnership with LLNL's Science & Technology Education Program (STEP) and funded by DOE Defense Programs, GTS-ITS sponsored the first Actinide Sciences Summer School. The six-week program included eight student participants. In 1999, the program was expanded to eight weeks and included 12 students.

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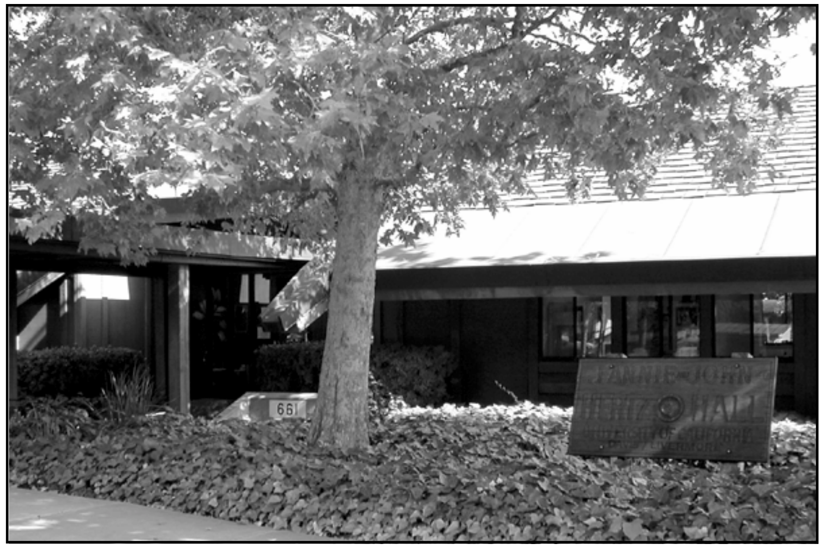
University of California Davis Department of Applied Sciences

Background



Hertz Hall outside the East gate at LLNL.

In 1963, Lawrence Livermore National Laboratory (LLNL) negotiated with the University of California (UC) and the U. S. Atomic Energy Commission to establish a graduate program. The goal was to provide military personnel and LLNL employees with the educational training necessary for obtaining advanced applied science degrees.

A new Department of Applied Science (DAS) was set up under the UC Davis College of Engineering, to permit professors from UC Davis and scientists from LLNL to serve as classroom instructors and thesis advisors. The DAS program trains scientists and engineers to work on complex problems of a multi-disciplinary nature. The DAS classrooms, located on University of California property outside of the gate on LLNL's eastern entrance, provides broad access to world-class science and engineering facilities.

Funding was obtained for a building to house the DAS's activities from the Hertz Foundation. This was combined with matching funds from UC to build Hertz Hall near LLNL, which was dedicated in 1977. Since then, UC Davis professors and LLNL scientists have established meaningful collaborations and entered into many career-enhancing activities.

Since 1963, 272 students have received Ph.D. degrees and 309 students received MS degrees through the DAS program. LLNLhas recruited about 35% of these DAS graduates, who have made important contributions to the Laboratory's mission.

Undergraduate Summer Institute

In 1984, Dr. Dennis Fisher (at the time, the Student Policy Committee chairman) initiated a program to recruit high-quality students to DAS and other Laboratory educational programs. An Undergraduate Summer Institute was established in 1985 under the joint sponsorship of the DAS, the Hertz Foundation, and several of the Laboratory's departments. Each year, this Institute brings about 30 top ranked physics and engineering undergraduates from around the country to Livermore for two weeks of lectures and hands-on work. A number of these students have subsequently pursued graduate study at DAS, or have participated in other Laboratory educational programs.

The Student Employee

This employee category was established to enable Ph.D. candidates to become halftime employees during the academic year and full-time employees during the summer months. The Student Policy Committee (SPC) advertises, selects, and monitors the progress of the DAS's students. The students' salaries and tuition are paid by LLNL, at an average cost per student of about $40,000 per year, excluding experiment-related expenses.

The Employee Students

These are full-time Laboratory employees who are pursuing an advanced degree with full pay. They are nominated by their supervisors and receive time off to attend classes either at DAS or at another approved institution of higher learning. The SPC determines their eligibility.

The Professors

Ten UC Davis professors teach, and are located, at Hertz Hall. Six other professors are located primarily at the UC Davis campus and one at UC Berkeley (UCB). The ten professors at Hertz Hall receive half of their academic-year salaries from UC Davis, and six months salary from LLNL (primarily through directorates). The other seven professors are paid entirely with UC funds. The Hertz Hall professors have recently begun obtaining their summer support either from a Laboratory program or from outside agencies, as is the case with most UC faculties.

The LLNL Research Advisor/Mentor

These mentors are often the best researchers and technologists at LLNL. Under their tutorship, students often complete high-quality theses in cutting-edge research. Most of these students take permanent positions at LLNL.

Present Status of the DAS

The graduate course structure at DAS is organized into "stem/options," with a sequence of courses leading to expertise in four specific topics:

- Millimeter wave and solid state electronics,
- Medical technologies,
- Computational science,
- Applied physics.

The following chart illustrates the number of persons in each educational program under the auspices of DAS. In FY99, 89 students were at various stages of their graduate studies, with many very close to completing their degrees. About 15 to 20 students are added each year to this program, giving it a steady-state student population of about 70. The LLNL directorates also fund the costs of supporting DAS students and professors: experimental facilities, technical support, supplies, and administration.

The Future

LLNL recently analyzed its future Ph.D. level employment needs. It became clear that a very wide range of specific skills will be needed. Analysis showed that the number of employees hired from DAS has dropped steadily in the past fifteen years and that today candidates with an appropriate level of education in the desired disciplines are more available than in the past. Therefore, changes are being made to better align LLNL's University policies. The LLNL Student Employee Graduate Research Fellowship (SEGRF) now not only includes DAS, but students from the other departments in the Engineering College at UC Davis and from Physics, Chemistry and Biology at UC Davis as well.

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Student Policy Committee

The Department of Applied Science (DAS), under the auspices of the School of Engineering at UC Davis, opened in the Fall of 1963 with six part-time instructors and 80 graduate students from LLNL, Sandia Livermore and the Military. In July 1966, the Laboratory Director at that time and an original faculty member of DAS, Dr. Michael May, appointed a six-member Student Policy Committee (SPC). Its purpose was to provide an institutional focal point, enhance interactions between LLNL/DAS and UC Davis, resolve mutual problems, and ensure future enrollment stability. The first Chairman of the SPC was Dr. Roger Batzel, who refined the graduate program and implemented policies governing graduate education for Laboratory employees.

Today, the SPC, appointed by the Director's Office, oversees a variety of student programs, and approves all graduate degree programs pursued by LLNL employees under Educational Assistance. Committee members are also called upon to discuss and establish educational policies, procedures and practices. The Committee meets once a month, and its membership is representative of higher-level management from a variety of organizations within the Laboratory. The SPC is responsible for providing management oversight of educational policy and practices at LLNL and has oversight of the following educational programs:

- The LLNL/DAS Student-Employee Program
- The Student-Employee Graduate Research Fellowship Program (SEGRF)
- The Student Guest Program
- The Graduate Student Term Program
- The Advanced Study Program

The SPC is responsible for approving requests for Student Guests and requests for Graduate Student Term appointments. The SPC reviews all graduate Career Development Plans and assesses the requests based on the value added from the degree to both the student and the Laboratory program. The Committee also takes into consideration the accreditation of the university and reputation in the specific discipline.

Other functions have also been added to the SPC. It now works with the Laboratory's Human Resources Department to administer the budget for supporting those expenses related to the DAS Students and LLNL's portion of the DAS Faculty's salary. The SPC also conducts performance reviews of the programs under its stewardship.

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Partnership for Environmental Technology Education (PETE)

PETE's Mission is "to provide leadership in environmental education and training through community and technical college partnerships with business, industry, government, and other education providers."

Introduction

The Partnership for Environmental Technology Education (PETE) is a national non-profit organization focused on assisting the nation's community and technical colleges in developing and delivering quality environmental education and training programs.

The Lawrence Livermore National Laboratory (LLNL) established PETE in FY1990 as a science and technology education initiative with sponsorship from the U. S. DOE. In 1994, PETE became an independent, non-profit corporation. LLNL, through the University Relations Program (URP), has continued to be an active and supportive partner.

PETE is organized into six regional partnerships supporting all 50 states, Puerto Rico, and the U.S. Territories, with over 600 participating colleges. The organization's primary sponsors have been the U.S. Environmental Protection Agency (USEPA), the National Science Foundation (NSF), the U.S. Department of Energy (DOE), and the U.S. Information Agency (USIA).

PETE college faculty received field experience in water quality monitoring as FAST interns.

Networking and Faculty Development

The key function of PETE is to facilitate effective networking of the colleges and their faculty among themselves and with their partners. This has allowed new Environmental Technician programs to be established and existing programs to expand faster than they otherwise could have through the sharing of curricula and access to mentoring colleagues. Networking is accomplished via the annual Instructor Resource Conferences in each PETE Region, which allow faculty to meet for a few days each year, introduce new members to the group, exchange information, and receive short-term training. During 1998-99, about 900 PETE college faculty participated in the Regional Conference series.

NSF funds the Faculty Associates in Science and Technology (FAST) Program, which is a core activity for Faculty Development. PETE college faculty are placed in 6–8-week internships in the public and private sectors. Our objectives are to get Environmental Technology faculty into the workplace, including the offices of state and federal regulatory agencies, for professional development and to establish relationships. One hundred twenty four (124) PETE college faculty participated in 1998-1999.

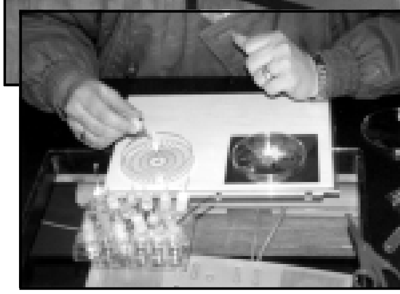
The Annual Summer Fellows Institute conducted by the NSF-funded Advanced Technology Environmental Education Center (ATEEC) is another important activity for our faculty. Science, math, and Environmental Technology instructors from PETE colleges and associated high schools participate in a two-week program designed for evaluating and improving Environmental Technology curricula. In

1998-99, sixty (60) PETE faculty participated in the Summer Fellows Institute.

Pollution Prevention Education and Outreach

PETE received a major grant from the USEPA Design for the Environment Program (DfE) during FY 1997-99. This program, the PETE-DfE Environmental Education and Training Alliance, focuses on curriculum development, faculty training and public outreach in pollution prevention. Key objectives have included the development and integration of pollution prevention (P2) content into community college curricula and the establishment of various training networks. P2 materials were developed and distributed to the colleges, training technicians for the automotive service, printing and wet/dry fabric cleaning industries.

The centerpiece of the Alliance activities is the Pollution Prevention in Chemistry Instruction Program. PETE partnered with Colorado State University and Merrimack College, the developers of Small-Scale and Microscale Chemistry instructional techniques, respectively, to use the PETE network to accelerate their implementation in U.S. schools and colleges. These revolutionary instructional techniques drastically reduce chemical waste generation, improve safety in teaching laboratories, and reduce operating expenses for the institutions. We are promoting implementation of these techniques nationwide through summer workshops and the establishment of PETE college training centers. The aim is to provide a permanent, self-sustaining source of training and support for Chemistry faculty in colleges, universities and high schools. By fall of 1999, one hundred eighty one (181) faculty have been trained and twelve (12) Microscale and fifty six (56) Small-Scale Chemistry Training Centers were established. Once this extensive training network is fully functional, we expect to reach up to 3000 chemistry faculty per year.



PETE College Chemistry faculty receiving instruction from the developer of Small Scale chemistry, Dr. Stephen Thompson, Colorado State University.

With funding from USEPA and DOE, PETE has also mobilized community and technical colleges to promote energy efficiency through training programs in their service areas. The Community Energy Efficiency Initiative has developed a national network of colleges to deliver energy efficiency workshops for local business and industry. As of mid-1999, eighty three (83) faculty from forty (40) PETE colleges have been trained and begun to deliver workshops. This program is also developing a model Associate Degree and Certificate Program for Energy Management Technicians. Plans call for utilizing the PETE organization to promote the nationwide implementation of these new programs in much the same way that a network of Environmental Technology programs was established.

Green Campus Initiative

Over the past several years, PETE has developed several Pollution Prevention (P2) initiatives that directly benefit the

"PETE has brought community and technical colleges significant opportunities benefiting our students, faculty and new program development. Participation in public-private partnerships such as PETE should continue to be a priority for our colleges in the years ahead."

Dr. David Pierce, President, American Association of Community Colleges

instructional programs and operation of its participating colleges. These include the Pollution Prevention in Chemistry Instruction Program, P2 and waste management training programs for automotive and print shops, and the Community Energy Efficiency Initiative. In 1996, with initial funding from USEPA, PETE began development of a program to link these initiatives and develop new activities to help our colleges establish themselves as model institutions in environmental education and management. PETE will assist participating colleges through a systems approach to evaluating opportunities to conserve resources and reduce waste generation. This could include energy and water consumption, the establishment of recycling programs, chemical acquisition and waste management, etc.

Tribal College Activities

A long-term objective of PETE has been and continues to be serving as a catalyst for the systemic improvement of Native American science education, particularly as related to the environment. PETE has consistently stressed the inclusion of Tribal College faculty in PETE-sponsored activities and developed a number of special initiatives. During FY1998-99, special one-day workshops were held for Tribal College science faculty and administrators in conjunction with the Northwest PETE Conferences, with about forty (40) participants each year. In collaboration with the Environmental Systems Research Institute (ESRI), two one-week workshops entitled "Introduction to Geographic Information Systems" (GIS) were held in Portland, Oregon, and Lansing, Michigan, with one hundred nine (109) Tribal College faculty participants. Tribal College faculty have also participated in the Faculty Associates in Science and Technology (FAST) Program and Small-Scale Chemistry workshops.

International Programs

PETE has also developed several international partnerships with universities in Mexico, Thailand and the Middle East. PETE's approach is to train faculty and provide access to existing curricula and other instructional resources to help them establish and maintain the institutional capability to deliver quality Environmental educational and training programs.

In 1998-99, the U.S. Information Agency (USIA) funded PETE to host nine senior faculty from five universities in Jordan, Lebanon, and the Palestinian Authority for introductory training in Geographic Information Systems (GIS). The group spent a total of four weeks at Brevard Community College in Florida and returned to the Middle East to establish GIS programs in their home institutions.

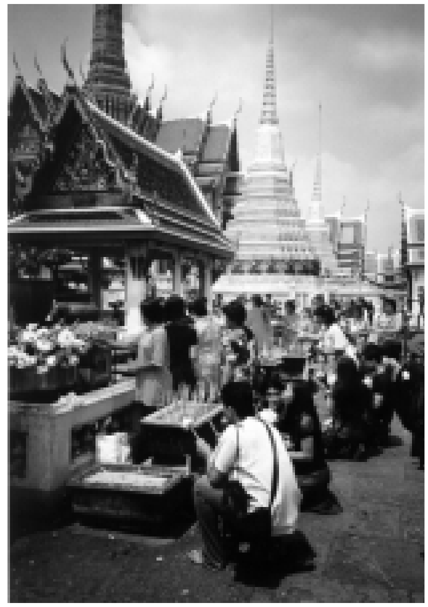
Nine senior faculty from the Jordan University of Science and Technology, the American University of Beirut, Lebanese American University, Birzeit University and the Palestine Polytechnic University participated in the USIA-funded GIS training program.

Mexico

With the execution of a Memorandum of Understanding in 1997 between PETE and Mexico's National System of Technological Universities - Universidad de Technologica (UT), an important partnership was established. The UT's are a new system of four year institutions that offer two-year Associates Degrees in several technology areas, including Environmental Technology. By the end of 1999, the UT system consisted of 36 campuses serving all thirty Mexican states. It has been estimated that eventually eighty percent of the UT campuses will offer Environmental Technology programs. In late 1998, PETE facilitated the development of partnerships between five UT campuses and three PETE colleges to deliver a train-the-trainer program in water/wastewater operations. This program is funded by the U.S. Agency for International Development (USAID) through the American Council on Higher Education and the American Association of Community Colleges (AACC).

Thailand

In 1998-99, PETE also partnered with the University of Hawaii/Honolulu Community College and Chulalongkon University in Bangkok for the establishment of a Center for Environmental Management and Training (CEMT) in Thailand. This program is supported by the U.S. Asia Environmental Partnership (USAEP) through the Council of State Governments (CSG). PETE will assist in establishing training programs for Thai trainers in areas such as industrial pollution prevention, chemical emergency response, water/wastewater treatment, etc. The program is being planned and implemented in close collaboration with the Thai government and the private sector.



PETE is delivering train-the trainer activities in Thailand.

The Future

Starting as an LLNL initiative, PETE has evolved over the past ten years into an internationally recognized non-profit organization that has had a far ranging impact on environmental workforce development and science/technology education in general. PETE will continue to make a contribution toward meeting the environmental education and training needs of the nation through the next decade.

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University of California Merced Planning

The Tenth UC Campus

In May 1995, the Regents of the University of California selected a site in Merced County near Lake Yosemite for development of the system's tenth campus. In December 1997, the new campus was designated the University of California, Merced.

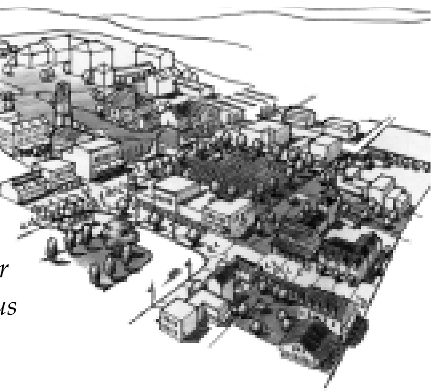
UC Merced will be the first new research university in the United States in the 21st century. The completely new campus will rise on 2000 donated acres of presently open grazing land, part of a total of 10,300 acres set aside for the overall university community. The campus will serve as the hub of a network of educational services, research activities and technological innovation reaching out to the San Joaquin Valley and the State.

The vision for technological innovation at UC Merced includes not only the establishment of world-class academic and research programs, but also the design and construction of the campus infrastructure and buildings with maximum consideration for environmental management and the stewardship of the site's important natural resources. UC Merced will be a "Green Campus."

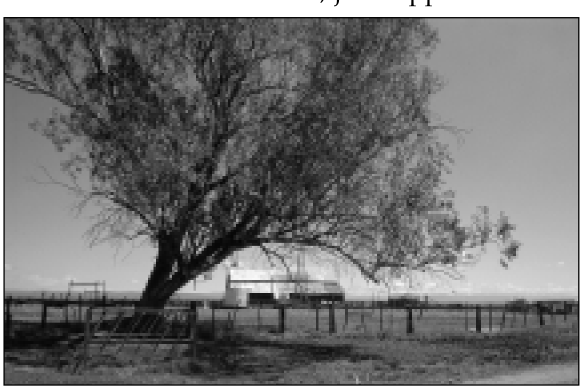
Current planning calls for the campus to open in the fall of 2004 with a goal of 1,000 students. Initial classes may be offered as early as Fall 2003 for up to 300 upper division and graduate students in three initial majors. UC Merced is planned to eventually serve 25,000 students.

Located approximately 100 miles northwest of Merced, LLNL expects to play a major role in the development and growth of UC Merced. Areas of cooperation under discussion, which will be formalized through a Memorandum of Understanding (MOU), include research collaborations, joint appointments for UC Merced faculty to do research at LLNL, and for LLNL scientists and engineers to teach at the University, student internship and co-op programs, and for the Lab to provide technical assistance in establishing UC Merced as a "Green Campus." LLNL will also participate in the planning and implementation of a Central Valley Initiative for systemic reform in K–12 education designed to dramatically improve the pipeline of students eligible to enter the University. The University Relations Program (URP) is serving as the focal point for the Laboratory's multi-dimensional collaboration with UC Merced.

The new tenth campus of the University of California at Merced represents an important step forward for the University and a vital future resource for the academic and economic development of the Central Valley. LLNL will play an aggressive role in helping to assure the success of UC Merced with the full expectation that this new addition to the UC system will become an important future partner and resource for the Laboratory in meeting its core programmatic requirements and those of the U. S. Department of Energy.



Aerial view of town center and Campus interface.



An opportunity to build a new research university campus from the ground up.

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Appendices

Publications

Workshops/Conferences

Students Associated with University Relations Program

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Workshops/Conferences

IGPP FY 99 Workshops/Conferences	# Attendees	Coordinators
March 29-April 1 1999 IMAGING THE UNIVERSE IN THREE DIMENSIONS: ASTROPHYSICS WITH ADVANCED MULTI-WAVELENGTH IMAGING Mariott Hotel, Walnut Creek, CA	120	Wil van Breugel, *IGPP, LLNL* Simon Labov, *IGPP, LLNL* Ron Wurtz, *IGPP, LLNL* Joss Balnd-Hawthorn, *AAO*

ILSA FY 98 Workshops/Conferences	# Attendees	Coordinators
September 30, 1998 MERCURY LASER WORKSHOP Wente Conference Center, Livermore, CA	53	Hector Baldis, *Director, ILSA*
November 23-24, 1998 JOINT INTERNATIONAL FUSION THEORY WORKSHOP ON HIGH FIELD SCIENCE '98 (United States and Japan) Lawrence Livermore National Laboratory	35	Toshi Tajima, *Univ. of Texas at Austin/LLNL* K. Mima, *Institute of Laser Engineering –Osaka University* Hector Baldis, *Director, ILSA*
ILSA FY 99 Workshops/Conferences		
February 17-20, 1999 3RD INTERNATIONAL WORKSHOP ON LASER PLASMA INTERACTION PHYSICS Banff Centre, Alberta, Canada	50	Hector Baldis, *Director, ILSA;* Wojciech Rozmus, *Univ. of Alberta, Edmonton, Canada;* Bruce Langdon, *LLNL X-Division*, Richard Lee, *LLNL V Division/Physics*
June 13-18, 1999 29TH ANNUAL ANOMALOUS ABSORPTION CONFERENCE Asilomar Conference Center, Pacific Grove, CA	140	Peter Young, *LLNL/Physics*, Scott Wilks, *LLNL/D&NT,* Hector Baldis, *Director, ILSA*
October 4-6, 1999 THE NIF SCIENCE USERS GROUP, FRONTIER SCIENCE AT THE NIF: EPISODE I Hilton Hotel, Pleasanton, California	150	Richard Petrasso, *MIT;* D. Arnett, *Univ. of Arizona;* C. Deeney, *Sandia NL;* B. Hammel, *LLNL* R. Kauffman, *LLNL;* C. Keane, *DOE/Washington* G. Logan, *LLNL;* Ann Satsangi, *DOE/Washington*

ISCR FY 98 Workshops/Conferences	# Attendees	Coordinators
March 30 – April 3, 1998 COPPER MOUNTAIN CONFERENCE ON ITERATIVE METHODS Copper Mountain, CO	100+	Steven Ashby, *Director, CASC* John Fitzgerald, *Acting Director, ISCR*
ISCR FY 99 Workshops/Conferences		
December 22, 1998 STRATEGIC PLANNING Pleasanton, CA	6	Steven Ashby, *Director, CASC* John Fitzgerald, *Acting Director, ISCR*
January 19, 1999 GENOMICS DATA WAREHOUSING FORUM Menlo Park, CA	15	Steven Ashby, *Director, CASC* John Fitzgerald, *Acting Director, ISCR*
April 11-16, 1999 COPPER MOUNTAIN CONFERENCE ON ITERATIVE METHODS Copper Mountain, CO	100+	Steven Ashby, *Director, CASC* John Fitzgerald, *Acting Director, ISCR*
June 10-12, 1999 SPARSE'99 Minneapolis, MN	100+	Steven Ashby, *Director, CASC* David Keyes, *Acting Director, ISCR*

ISCR FY 99 Workshops/Conferences	# Attendees	Coordinators
June 23-25, 1999 SCALABLE LINEAR SOLVERS WORKSHOP Livermore, CA	40	Steven Ashby, *Director, CASC* David Keyes, *Acting Director, ISCR*

MRI FY 98 Workshops/Conferences	# Attendees	Coordinators
November 11-13, 1997 **POSITRON CONFERENCE** **Lawrence Livermore Nat'l Laboratory** ***Materials Research Institute***	30	Rich Howell, *Physics, LLNL*
June 8-10, 1998 **TRI-LAB COURSE: DISLOCATIONS IN MATERIALS** **Hilton Hotel – Pleasanton, CA**	50	Wayne King, *Chemistry and Materials Science, LLNL*
June 11-12, 1998 **NIST/LLNL WORKSHOP ON WORK HARDENING AND DISLOCATION PATTERNING IN METALS** **Hilton Hotel – Pleasanton, CA**	30	Wayne King, *Chemistry and Materials Science, LLNL* Robb Thomson, Lyle Levine, *National Institute of Standards and Technology*
June 28 -July 3, 1998 **INTERNATIONAL WORKSHOP ON ELECTRONS CORRELATIONS AND MATERIALS PROPERTIES** **Crete, Greece**	42	Tony Gonis, *Chemistry and Materials Science, LLNL* Nick Kioussis, *Cal. State Northridge*

MRI FY 99 Workshops/Conferences		
April 1-2, 1999 **GRAIN BOUNDARY ENGINEERING WORKSHOP** **Sheraton Hotel – Pleasanton, CA**	12	Wayne King, *Chemistry and Materials Science, LLNL*
Sept 13-14, 1999 **CLC NOVEL MATERIALS WORKSHOP** **Lawrence Livermore Nat'l Laboratory** ***Materials Research Institute***	75	Harry Radousky, *MRI, LLNL* Shirley Chiang, *UC-Davis* Susan Kauzlarich, *UC-Davis*

HBCU-MI FY 98 Workshops/Conferences	# Attendees	Coordinators
February, 1998 **WAVELETS: THE LATEST BIG SPLASH IN SCIENCE, ENGINEERING, IMAGING AND GRAPHICS** **Washington D.C.**	25	Colm Mulcahey, *Spelman College* Farid Dowla, *LLNL*

Students Associated with University Relations Program

FY98–99 Students in CAMS

Arjoumand, Ali	UC Davis
Balakrishnan, Sharada	UC Riverside
Bennett, Jacqueline	UC Riverside
Bergquist, Bridget A	Woods Hole Oceanographic Institute
DeRubertis, Diana	UC Berkeley
Divine, Kevin	University of New Mexico, Albuquerque
Dull, Robert	UC Berkeley
Espinosa, Daniel	San Jose State University
Frantz, Christopher	UC Riverside
Gaudinski, Julia	UC Irvine
Gilman, Douglas	UC Davis
Hom, Damon	Contra Costa College
Hoopai, Randy	San Jose State University
Hooper, Linda	UC Riverside
Jaffer, Ali	UC Davis
James, Elizabeth R.	Oregon State University
Jeske, Stephanie	Indiana University
Leal-Bautista, Rosa Maria	Northern Illinois University
Love, Adam	UC Berkeley
Mondrala, Scott	UC Riverside
Pawley, Norma H	Cornell University
Qui, Yong Chang	UC San Francisco
Rauser, David	San Jose State University
Raymond, Peter	College of William and Mary
Roark, E. Brendan	UC Berkeley
Siekmann, Jonathan	UC Davis
Velazquez-Oilman, Guadalupe	Northern Illinois University
Westbrook, Jessica	High School (General)
Whitehead, William	UC Berkeley
Zermeno, Paula	San Jose State University

FY98–99 Students in IGPP

Alves, David R.	UC Davis
Basu, Antara	UC Berkeley
Becker, Andrew	University of Washington
Bilek, Sue	UC Santa Cruz
Bischof, Otto B.	UC Davis

FY98–99 Students in IGPP (Continued)

Bratton, Clayton	UC Davis
Catlos, Elizabeth	UC Los Angeles
Cooke, Jeffrey B.	UC San Diego
Dearborn, Xander	UC Santa Cruz
De Breuck, Carlos	University of Leiden, Netherlands (Netherlands)
De La Cerda, Anthony	UC Davis
Eckart, Megan	UC Berkeley
Fisher, Robert	UC Berkeley
Geha, Marla	UC Davis
Gold, Ben	UC Davis
Halderson, Eve	UC Berkeley
Harlow, Jason B.	Pennsylvania State University, State College
Havens, Emily	UC Santa Cruz
Kapp, Paul	UC Los Angeles
Lee, Brian	University of Michigan, Ann Arbor
Liang, Chyng	UC Berkeley
Liu, Mike C.	UC Berkeley
Marx, Robert	University of Washington
McCabe, Caer	UC Los Angeles
McCarthy, Chris	UC Los Angeles
McIntosh, Timothy K	UC Davis
Nadeau, Robert	UC Berkeley
Nelson, Cailin A	UC Berkeley
Neroda, Elizabeth	Occidental College
Opoku-Adusei, Mark	UC Los Angeles
Parriott, Joel	University of Michigan, Ann Arbor
Patience, Jennifer	UC Los Angeles
Piechota, Thomas C.	UC Los Angeles
Price, Trevor R	UC Davis
Roe, Henry	UC Los Angeles, UC Berkeley, UC Davis
Rorabeck, Andrew J.	McMaster University
Rottgering, Hubertus J.	University of Leiden, Netherlands (Netherlands)
Russell, Sara	UC Santa Cruz
Salmonson, Jay	UC Davis
Scott, Henry P.	UC Santa Cruz
Steffes, Adam	UC Davis
Stern, Daniel	UC Berkeley
Syphers, David	Las Positas College
Truelove, J. Kelly	UC Berkeley
Vandehei, Thor J.	UC San Diego

FY98–99 Students in ILSA

Allen, Adrian	Oxford University
Alves, Rosa	UC Davis
Anderson, Christian	UC Davis
Chan, James	UC Davis
Depierreux, Sylvie	Ecole Polytechnique, France
Desparois, Alain	University of Montreal, Canada
Gibson, David	UC Davis
Landahl, Eric C	UC Davis
Li, Kebin	UC Davis
Loveridge, Andrew	Oxford University
McNary, Jason	UC Riverside
Myers, Nancy	UC Davis
Rieben, Robert	UC Davis
Rogers, Phillip N.	UC Davis
Thamboon, Prissana	UC Davis
Troha, Anthony	UC Davis
Unterberg, Ezekiel	University of Tennessee
VanMeter, James	UC Davis

FY98–99 Students in ISCR

Adams, Mark	UC Berkeley
Adiwijaya, Igg	Rutgers University
Alme, Henry	DAS
Austin, Travis M.	University of Colorado, Boulder
Ballinger, Lora	University of Utah
Bertram, Martin	UC Davis
Bonnell, Kathleen	Cal State, Domingues Hills
Brunner, Thomas	University of Michigan
Bullok, Dan	University of Illinois
Chartier, Tim	University of Colorado, Boulder
Covello, Paul	DAS
Darlington, Rebecca Mattson	DAS
Durrengerber, J. Kevin	Cal State Hayward
Dursi, Jonathan	University of Chicago
Ellis, Daniel	Brigham Young University
Gallup, Richard	UC San Diego
Giamporcaro, Matt	Boston University
Higginson, Chris	University of Colorado, Boulder
Hoel, Zoe A.	UC Davis
Hong, Rithea	Texas A&M University

FY98–99 Students in ISCR (Continued)

Hsia, Andy C.	UC Berkeley
Iontcheva, Ana	UC Davis
Jeunnette, Mark	University of Chicago
Karavanic, Karen L.	University of Wisconsin, Madison
Karchin, Rachel	Stanford University
Kim, Chisup	Texas A&M University
Kirby, Imelda	University of Washington
Knepley, Matthew	Purdue University
Koning, Joseph M.	UC Davis
Kuester, Falko	UC Davis
LaMar, Eric	UC Davis
Laney, Daniel	DAS
Lee, Gary	UC Berkeley
Lehman, Sean	DAS
Miller, David	DAS
Milota, Andre D.	UC Davis
Morris, Scott	University of Utah
Nault, David	University of Cincinnati
Niebur, Glen L.	UC Berkeley
Pearlman, Jonathan L.	UC Berkeley
Perry, Jason	University of Kentucky
Philip, Bobby	University of Colorado
Pierce, Tim	DAS
Pomeranz, Alexandru	UC Davis
Rantakokko, Jarmo	UC San Diego
Reid, Lyn R.	University of Washington
Rochez, Johnathan	DAS
Sager,Natasha	Los Positas College
Saha, Subhasis	DAS
Salmonson, Jay	DAS
Scully, Kevin	UC Irvine
Tamason, Alex	University of Washington
Thomas, Jay Feltus	DAS
Thomas, Megan C.	UC Berkeley
Thornquist, Heidi	Rice University
Tobin, Ben	Northern Arizona University
Tomov, Stanimire	Texas A&M University
Vlack, Kevin	University of Illinois
Weiss, Christian	Technische Universitae
Wickett, Michael	DAS

FY98–99 Students in ISCR (Continued)

Wittman,Michael	UC Davis
Young,Yuan-Nan	University of Chicago
Zikatanov, Ludmil	Pennsylvania State University

FY98–99 Students in MRI

Allen, Adrian	University of Oxford
Bacaloni, Marco	UC Los Angeles
Bauer, Eric	UC San Diego
Bley, Richard	UC Davis
Chantasiriwan, Somchart	UC Santa Barbara
Chau, H. T.	UC Davis
Chau, Ricky	UC San Diego
Chiang, B.	UC Davis
Chun, Michael	UC Los Angeles
Cohen, Robert	UC Davis
Consorte, Charles	UC Davis
Couture, Aaron J.	University of Notre Dame
Devlin, C.	UC Davis
Dickey, Robert	UC San Diego
Dilley, Neil	UC San Diego
Driscoll, D.	UC Santa Barbara
Enjalran, Matthew J	UC Davis
Fallis, Mark	UC Davis
Fogliatti, David W	UC Los Angeles
Freitos, Paul	UC Davis
Futaba, D.	UC Davis
Gajewski, D.	UC San Diego
Guo, Jingyan	UC Riverside
Hart, Gus	UC Davis
Hattass, Mirko	Goethe University Frankfurt
Holm, Steve	UC Los Angeles
Johnson, Tracey	UC Davis
Kadow, C.	UC Santa Barbara
Krupski, Amanda M.	San Jose State University
Kwok, Hidong	UC Riverside
Liberman, D.	UC San Diego
Lindenberg, Aaron	UC Berkeley
Lotz, Ryan	UC Santa Barbara
Loui, Al	UC Davis
Loveridge, Andrew	University of Oxford

FY98–99 Students in MRI (Continued)

Lozano, Richard	UC Davis
Luo, Tzy Jiun (Mark)	UC Davis
Machicoane, Guillamme	Univ. of Paris
Maranville, Bran	UC San Diego
Martin, Tracie	UC Davis
Martinez, Rudy	UC Los Angeles
Mayeri, Daniel	UC Davis
McBride, Mary	UC Davis
Newman, Mike	Univ. of Connecticut
Niedermayr, Thomas	Univ of Paris
O'Loughlin, Jennifer L.	UC Los Angeles
Okupe, Ola	UC Davis
Pask, John E.	UC Davis
Paskowitz, Mike	UC Davis
Payne, A.	UC Davis
Raczkowski, David	UC Davis
Richardson, Christopher	Johns Hopkins University
Ruehlicke, Christiane	Univ. of Bielefeld, Germany
Shapiro, Alex	UC San Diego
Slepoy, A	UC Davis
Smith, Christine	UC Davis
Taylor, Boyd R	UC Davis
Thayer, Gayle	UC Davis
Tsyfanskiy, Vyach	UC Los Angeles
Wallace, Charles H.	UC Los Angeles
Wohlert, Stefan	UC San Diego
Yang, Chung-Sung	UC Davis
Yang, T. J.	UC Riverside
Zhang, Chunli	UC Irvine

FY98–99 Students in URP

Basso, Amy	UC Riverside
Blobaum, Kerri J.	Johns Hopkins University
Bonilla, Fabian	UC Santa Barbara
Bowles, Anita M.	Harvard University
Cavazos, John	University of Massachusetts, Amherst
Clark, Trevor	Stanford University
Cochran, Elizabeth	UC Santa Barbara
Doroudian, Macan	UC Los Angeles
Elrick, Scott	UC Riverside
Fuchs, Julien	Inst. Nat'l Research, Quebec

FY98–99 Students in URP (Continued)

Funk, Richard	UC Riverside
Geralt, Algerd	UC San Diego
Glass, Jennifer	UC Berkeley
Hsu, Chu-Chang	UC Los Angeles
Hsu, Heileen	UC Berkeley
Keen, Diana	UC Davis
Levy, Carla	Harvard University
Masterson, Brett	University of Texas, Austin
McCray, Christophe	Hampton University
McDaniel, Shannon	University of Washington
Palusinski, Iwona	University of Arizona
Perkins, Amy E.	Brown University
Phillips, Joseph Perry	University of Michigan, Ann Arbor
Rogers, Martin W	University of Tennessee
Rogers, Tamara M	UC Santa Cruz
Santiago, Rica D.	San Jose State University
Veal, Marlon D.	UC Santa Cruz
Williams, Shara C.	UC Berkeley
Xu, Heming	UC San Diego

FY98–99 Students in STEP

In FY98, STEP college students that were on site at LLNL were 126 compared to the total of 230 students that directly participated in STEP projects. In FY99, STEP college students on site were 140 compared to the total of 384 that directly participated in STEP projects. The STEP students that were not on site participated in STEP projects while attending STEP sponsored courses in their classroom.

UNIVERSITY RELATIONS PROGRAM

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